# MODERN TECHNICAL DRAWING

GEORGE ELLIS

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# MODERN TECHNICAL DRAWING

Walter T. Steilberg

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A HANDBOOK DESCRIBING IN DETAIL THE PREPARATION OF WORKING DRAWINGS, WITH SPECIAL ATTENTION TO OBLIQUE AND CIRCLE-ON-CIRCLE WORK, ORTHOGRAPHIC, ISOMETRIC AND OBLIQUE PROJECTIONS, PRACTICAL PERSPECTIVE, FREEHAND DRAWING AND "SETTING-OUT"; ALSO VARIOUS STYLES OF LETTERING

CLASS
PB 1
¼BD
CAT FOR
ENVIRON DESIGN
BU

BY

GEORGE ELLIS

Author of "Modern Practical Joinery," "Modern Practical Carpentry," etc.

ILLUSTRATED BY NEARLY 300 EXAMPLES

LONDON
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# PREFACE

THE object of this little work is to meet a frequently expressed need for some practical instruction in Builders' Technical Drawing as pursued in the modern Office and Workshop, to bring together in due order the various methods and devices obtaining in the preparation of Working Drawings, and to explain their principles and indicate the suitability or otherwise, for the purpose in view.

Although no attempt has been made to treat the subject exhaustively, sufficient information, it is hoped, has been given to enable the beginner to reach a considerable degree of proficiency without further aid than the numerous examples provided will afford. It is also believed that Teachers of Drawing may find in these examples some useful suggestions for their own demonstrations.

For the sake of completeness, a form of Technical Drawing not usually associated with draughtmen's work, but none the less important—viz. the planning and graphic description of work for the use of artisans in the workshop known collectively as the "Setting-Out" of work—is included and treated with a fulness not hitherto attempted, and this, it is hoped, will prove of service to foremen and others.

I take this opportunity of acknowledging the assistance of Miss Gertrude Ellis and Mr George Ellis, jun., in arranging and preparing the book for the press.

THE AUTHOR

ILFORD,
*September* 1913.

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# Modern Technical Drawing

## CHAPTER I

## VARIOUS KINDS OF TECHNICAL DRAWING

Technical Drawings—the requirements of, need of conventions. Orthographic Projection—principles of. Isometric Projection—its uses and defects. Oblique Projection—various modifications. Perspective Projection — what it is. Freehand Sketches—advantages of. Practical Geometry—its use to the draughtsman. Working Drawings—essentials of. Workshop Drawing

**Technical Drawing** is, in effect, the language of the workshop and drawing office, the means by which the ideas or intentions of the designer are conveyed to the constructor in a much more definite and understandable manner than can be done by the most elaborately written or spoken directions.

It will be readily understood that, to avoid confusion, universally accepted methods or conventions must be adhered to in preparing such drawings, otherwise the user would be in the same position as one trying to read a book written in a foreign language ; even the latitude allowed the artist or pictorial draughtsman in depicting his emotions or impressions would render technical drawings useless for their purpose. We must speak in a common language to be understood by all.

But the requirements of the constructive arts are so numerous and varied that even within the circumscribed sphere of the building trades several different types or classes of drawing are necessary. Each of these will be dealt with as fully as may be needful for elementary work in the succeeding chapters, and the descriptions given here are rather in the nature of a summary of the advantages and disadvantages—or at least the limitations of each kind—than an instruction in their preparation.

**Orthographic or Perpendicular Projection.**—This is the commonest and most useful method of producing drawings, but its meaning is not always obvious to the inexperienced, for it is a graphic language that generally has to be acquired step by step. In this form of drawing, which is usually adopted for architectural "plans" of buildings and for working drawings, every part is drawn as if immediately in front of the observer, no allowance for distance in the parts of the object from the observer being made; it is the unaccustomed appearance which results when this method is used that is so confusing to the uninitiated, but the procedure is essential if direct measurements and correct angles are to be obtained from the drawings. In this kind of drawing the observer is supposed to stand directly in front of the object, and to see all its parts upon that face at the same time, and it will be obvious that, if this is so, he cannot see more than one front or surface at a time; consequently, in depicting any solid, as many "projections" or views have to be made as the solid has sides or surfaces. As, often, the several sides do not possess distinctive features by which they can be readily identified, a conventional or generally-agreed-upon set of terms are used to describe these views, mainly based upon their relative position to the ground. Thus the surface or side which is supposed to rest upon, or is parallel to, the surface of the ground is termed the PLAN; that surface which is at right angles to the ground—*i.e.* vertical—is termed the ELEVATION, and as there are only three dimensions to any solid—viz. length, breadth and thickness—it is obvious that we can depict any regular solid by three views or projections showing these dimensions. One of these will be the PLAN, the other two will be ELEVATIONS, which are distinguished as circumstances dictate, either as the " front elevation " and " end elevation," or, as in the case of buildings, according to the point of the compass which they face, as north, south, east or west, etc., elevations. If the object depicted has an interior which it is desired to show, such a view is termed a SECTION, which means a cutting, the view produced being that which the observer would see if the object were cut through on, or by, a plane parallel to that upon which the drawing is made.

As the object here is merely to summarise the characteristics of the various kinds of drawing, further details will be deferred until the chapter dealing with the method of making orthographic projections is reached. The drawings upon page 4 illustrate, by means of a simple solid, the several methods herein described, from which a ready comparison of their effect can be drawn.

**Isometric Projection or Projection of Equal Measures** is a method used to depict three sides of an object in one drawing, thus showing its length, breadth and thickness with a minimum of work and a maximum of clearness; it is a suitable and convincing method for rectangular objects only, as those with inclined surfaces are so distorted in the drawing that no true impression of their shape is conveyed by this method.

Its limitations will be dealt with more fully in Chapter VI. Here it will be sufficient to draw attention to the inclined mitre in the " frog " of the brick depicted in Fig. 6, page 4, wherein the junction between the two slopes is indicated by a vertical line, which common-sense tells us it is not. However, it is impossible to show it in any other way by the rules of isometric projection.

**Oblique or Parallel Projection** is a still simpler method than the last for showing three sides of an object in one drawing. Simple rectangular solids, or those having regular curved outlines such as mouldings, can be shown in this way easily and graphically (see Fig. 7, page 6). In this method the chief face, or elevation, is drawn as it exists

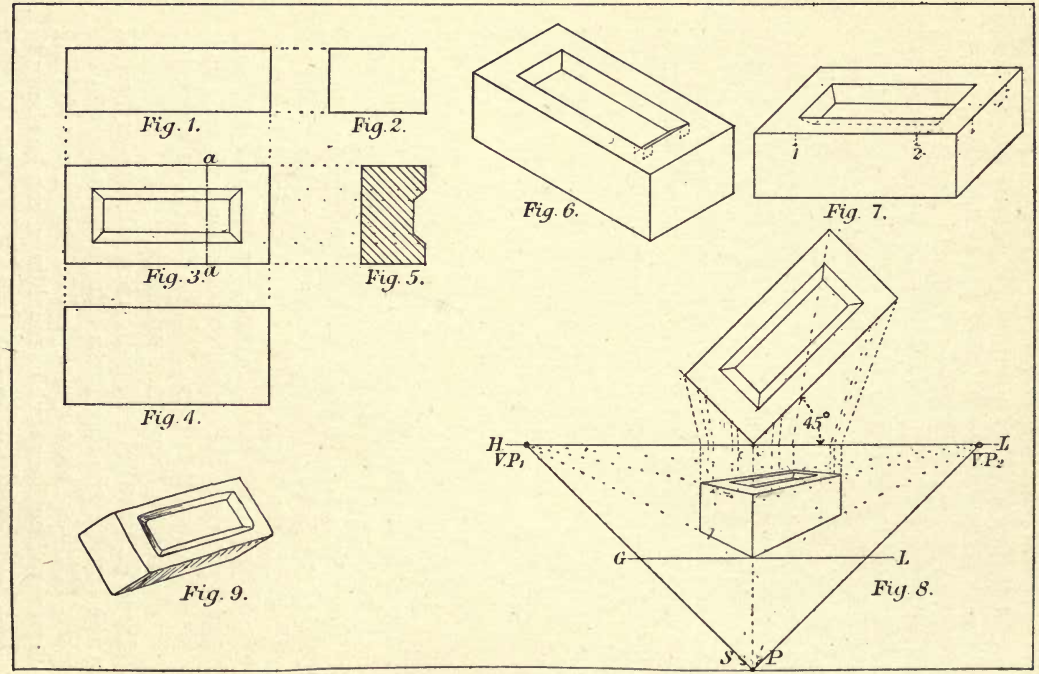


Fig. 1.
Fig. 2.
a
Fig. 3.
a
Fig. 5.
Fig. 4.
Fig. 6.
1
2
Fig. 7.
45°
H
V.P.1
L
V.P.2
G
L
Fig. 8.
S
P
Fig. 9.

Comparative Methods of Drawing the same Object

Figs. 1 to 5. Orthographic. Fig. 6. Isometric. Fig. 7. Oblique. Fig. 8. Perspective. Fig. 9. Freehand or is intended, and the two adjacent sides are then drawn at a common oblique angle, most frequently 45°, all of the sides which are parallel in the object being drawn parallel in the projection. The chief drawback of this method is that the oblique sides appear out of proportion to the adjacent side.

Two modifications of the method have been adopted to counteract this effect: one by drawing the oblique side to half the scale of the parallel side; the other by making an auxiliary drawing from which the projection is made upon a special picture plane.

The first method sins against a cardinal rule of draughtsmanship, in using two scales or proportions upon one object, a fruitful source of error. The second is a complicated and involved process, with little to recommend it upon the score of economy of time. The three methods are explained in detail in Chapter VII., together with another method used by the author for some years, but now published for the first time.

**Perspective or Radial Projection** represents solids by means of diagrams in which each geometrical "point" is defined upon the plane of the drawing by a projector, which passes through the actual point represented and through a fixed point which is the same for all the points in the drawing. The position of this fixed point in relation to the plane of the drawing and to the object represented must be selected within certain limits, or an appearance of distortion will result in the drawing.

This method of drawing shows objects in the positions in which they appear to be in relation to the eye of the observer, and not as they really exist. Thus a long, straight track of railway lines is made to appear as though converging in the distance, though of course they are in fact parallel, but by representing them in this manner we produce the impression of distance for the observer.

It is not necessary in this small treatise to explain fully the theory of linear perspective, for it is only intended to give the abbreviated method commonly used by technical draughtsmen.

**Freehand Drawing and Sketching.**—This term implies drawing or sketching in which the hand of the worker is " free " in the sense of not being guided or restricted in its action by any mechanical means such as squares, compasses or rulers.

The result depends upon the skill or practice of the sketcher. It is an acquirement worth cultivating, as often a graphic sketch made in a few seconds will illustrate one's meaning much more readily than a laborious verbal description. In Chapter IX. will be found a few hints and devices that the author has found of assistance in his own practice.

**Practical Geometry.**—Geometry is defined as that branch of mathematics which treats of the measurements of lines, surfaces and solids, with their various relations ; and practical geometry is the method of applying its principles to the requirements of trades or handicraft.

Almost all mechanical drawing is based on geometrical principles, and in the chapter which is devoted to this subject a selection of examples is given in which it is shown how these well-established principles may be utilised in solving the everyday problems of the workshop and drawing office.

**Working Drawings.**—The term, working drawing, is commonly used by architects to indicate those drawings which they supply to builders as part of the necessary directions for doing the work. These drawings vary in scale from $\frac{1}{8}$ in. to the foot, or even smaller, up to full size, according to convenience or necessity. Further working drawings are generally made from these, for the direct use of the workman ; these are, in carpenters' and joiners' work particularly, practically always full size, and are generally made (or set out, as it is termed) by the foreman or a specially efficient workman termed a "setter-out." These full-size drawings are usually made upon prepared boards termed

" rods," and it is from these that the working lines are transferred to the material, or, as in the case of brickwork and masonry, the working templets are made. It might perhaps be convenient to distinguish these latter as " workshop " drawings, but, of course, the distinction would be a purely arbitrary one.

## CHAPTER II

# DRAWING INSTRUMENTS AND APPLIANCES—HOW TO USE THEM

The Drawing Board—sizes, materials, attachments, a reversible board. Squares — T-square, most serviceable kind. Set Squares—useful sizes, various materials and their defects. French Curves. Instruments—choice of. Compasses—sizes, uses, etc. Ruling Pen. Parallels. Protractors—description, various kinds, construction of, method of using. Drawing Papers—choice of, where obtainable, standard sizes. Pencils—degrees, making compass pencils. Rubber—kinds, and methods of using. Drawing Pins. Extractors. Drawing Inks—how to prepare and use. Tracing Paper and Cloth—sizes and use of. Scales—description, making scales, the representative fraction, method of dividing, diagonal scales, how constructed and read

**The Drawing Board.**—This is a flat board with its edges truly square and parallel, made in certain standard sizes to suit the paper generally used. The two most useful sizes for students are "half imperial," measuring about 16 in. × 23 in. × $\frac{5}{8}$ in. thick, suitable for elementary work, and "imperial," 32 in. × 23 in. × $\frac{7}{8}$ in. for more advanced work; professional draughtsmen nearly always use a larger size, "double elephant," 28 in. × 41 in., but this size is seldom required by students. The drawing board may readily be made by a joiner, although it is hardly possible to obtain such well-seasoned and suitable material as that used by the leading firms of instrument-makers.

The best boards are made of American yellow pine, free from knots, square jointed and battened at the back, the battens fixed with domed screws sunk in slots and working on brass plates, to allow for swelling and shrinking of the board. In some makes the backs are grooved to prevent warping, as shown in Fig. 1 (the under side of a battened drawing board) and in the enlarged detail, Fig. 2; and the working edge (left-hand end) inlaid with an ebony slip to prevent wear of the softer pine.

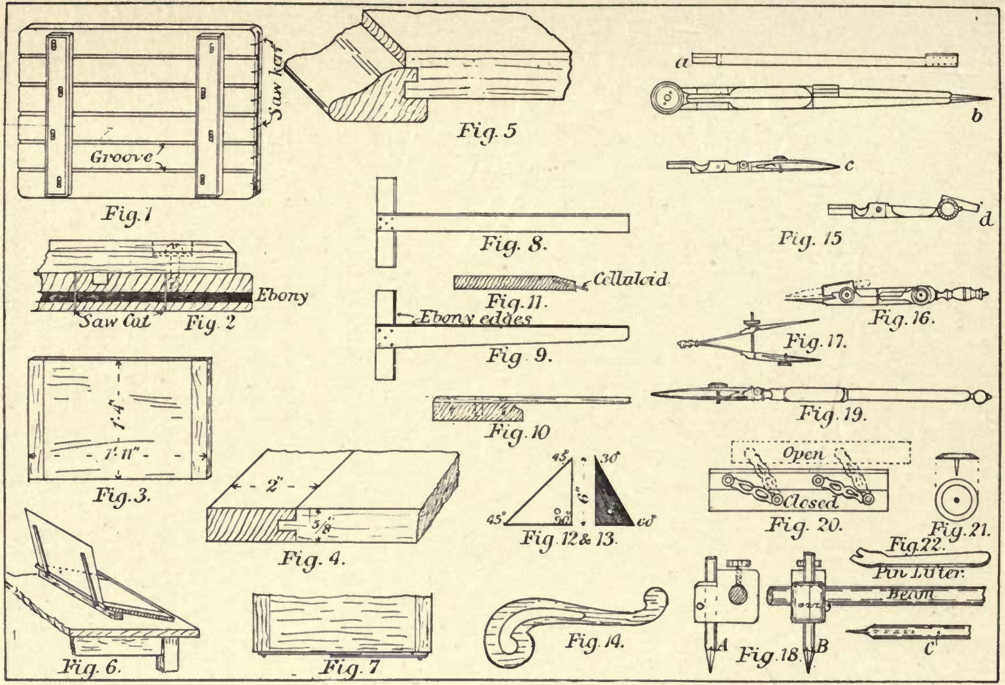
A cheaper kind is the clamped board, Figs. 3 and 4. These are not so reliable as the above, for the shrinkage of the panel causes the ends of the clamps to project, and if the square is used from that edge a faulty line is produced. They will, however, answer the purpose of beginners for some time, if they are trued up occasionally, and they are much cheaper than the battened variety.

A very reliable form of board, which the author designed for his own use some years ago, is shown in Fig. 5. It is easy to make, and has the advantage that both sides of the board may be used, and there is no possibility of the panel splitting. The board is glued up and cleaned off to the required size, then the ends are grooved exactly one-third of the thickness. Two clamps of hard-wood, straight-grained mahogany for preference, about the same thickness as the board, are prepared with a similar groove to that in the board, when these are fitted on as shown, just "hand-tight," they will allow the board to swell or shrink, but prevent it casting. Of course they must be fitted with dry joints—that is, not glued. The depth of the working edge must be a trifle more than the thickness of the stock of the T-square used.

A useful attachment to the board, which the joiner student can make for himself, is the "copy" holder shown in Figs. 6 and 7. These may be two thin strips of mahogany, one attached directly to the back edge of the board by means of a round-headed screw, the other pivoted similarly to a short block or fillet, equal in thickness to the opposite slip, and fixed to the board so that the first slip folds down within it, whilst the second folds over the first. They should work stiffly, and the edge of the board and the fillet should be bevelled to throw the holders backwards when open. A tilting bar (see Fig. 6), about 18 in. × 2 in. × 2 in. is useful for tilting the board up at a convenient angle for work.

**The T-Square**, Figs. 8 and 9, is used chiefly for drawing horizontal lines. It should be of the same length as the board used, and those with tapering blades are to be preferred. The stock should be rebated and chamfered as shown in the enlarged detail, Fig. 10, so that if the paper overhangs the board it will not throw the square out of place. The chamfering prevents the set square catching upon the edge, should the stock lie out of level. The blade should be screwed to the stock, and in the larger sizes dowelled also, as shown in Fig. 10, but not glued, as it is necessary to take it off for re-shooting at times. The top edge should be chamfered down to $\frac{1}{16}$ in. thick, so that lines may be seen easier, also to reduce the risk of irregular lines through alteration of the angle at which the pencil is held. Many draughtsmen use a square which has a strip of celluloid sunk in the working edge (see Fig. 11), as lines can be seen through it; it is chiefly of service when inking-in large drawings.

**Set Squares**, Figs. 12 and 13, are triangles used in conjunction with the T-square for drawing vertical, perpendicular and parallel lines at any angle. They are made of various shapes, materials and sizes. The most useful sizes and shapes are those known as 45° and 60°, and from 4 in. to 8 in. in height. The 45° square, Fig. 12, is the triangular half of a true geometrical "square"; one angle is a right angle, the other two contain 45 degrees each, between the adjacent edges. The 60°, Fig. 13, has angles of 90°, 30° and 60° respectively, and it might as rightly be termed "30°," but is generally described as above. They are made in hard-woods, vulcanite and celluloid. Wood is not to be recommended; it alters in shape and has to be too thick to be manageable: exception may be made to this general statement in the case of "framed" or open squares made of hard-wood with the edges chamfered upon one side. These are expensive. Celluloid is the most useful, as it can be seen through, a great advantage in elaborate drawings, but it has a serious draw-


Saw kerf
Groove
Fig. 1
Fig. 5
a
b
c
d
Fig. 15
Fig. 8.
Cellulcid.
Fig. 11.
Ebony
Saw Cut
Fig. 2
Ebony edges
Fig. 9.
Fig. 16.
Fig. 17.
1' 4"
1' 11"
Fig. 3.
Fig. 10
Fig. 19.
Open
Closed
Fig. 20.
2"
5/8
Fig. 4.
45°
30°
6"
90°
60°
Fig. 12 & 13.
Fig. 21.
Fig. 22.
Pin Lifter.
Beam
Fig. 6.
Fig. 7
Fig. 14.
A
Fig. 18.
B
C

Drawing Instruments and Appliances

Fig. 1. Battened Drawing Board. Fig. 2. Detail of Working End. Fig. 3. Clamped Board. Fig. 4. Enlarged Detail of Clamp. Fig. 5. A Reversible Board. Fig. 6. A Folding Copyholder. Fig. 7. Plan of Same. Figs. 8 to 10. T-Squares and Details. Figs. 12 and 13. Set Squares. Fig. 14. French Curve. Fig. 15. A Half Set of Compasses. Fig. 16. Bow Compasses. Fig. 17. Spring Bow Pen. Fig. 18. Beam Compasses. Fig. 19. Ruling Pen. Fig. 20. Parallel Rules. Fig. 21. Drawing Pen. Fig. 22. Pin Lifter

back, it casts freely in warm weather, and thus will rise from the paper in places, allowing the pencil to slip under and make an irregular line. It may be restored to shape by dipping in hot water and placing under a weight. Vulcanite is cheaper and stands well, but is liable to break if dropped ; probably it is the most popular material.

**Architectural or French Curves**, Fig. 14.—These are shaped pieces of thin pear-wood or celluloid, cut into various circular or elliptic designs for the purpose of guiding the inking pen when drawing curved lines. Their use with the pencil is to be deprecated, as tending to discourage that freedom of hand necessary for good draughtsmanship. Their methods of use will be dealt with in the next chapter.

**Instruments.**—There are to be found in the shops that deal in artists' and students' requirements an immense variety of these "tools" and appliances, and the inexperienced reader of a maker's catalogue is bewildered by the numerous varieties of the same instruments shown therein, and, without advice from an experienced draughtsman, is very likely to make a wrong selection. Many of the instruments shown are only of service to specialists; others are merely time savers, the work they are designed to execute being within the capacity, with a little skill on the part of the user, of much lower-priced instruments of general utility. With the former it is not the purpose of this book to deal. Only those things that may be considered *necessary* for the ordinary workman student's purpose will be described. It would be useless attempting to indicate what prices should be paid, as tastes will differ as to the design of instruments. This, with the quality and amount of finish given to them, has considerable influence upon the cost. All that can be stated in this direction is that the higher priced article is generally the cheaper in the long run—that is, it will remain in good order the longest time. British-made instruments are usually more reliable than foreign made, and they should be purchased either from the makers or dealers who specialise in these things rather than from the ordinary stationers or second-hand shops ; these latter are pretty sure to stock "shoddy" foreign-made goods.

**Compasses.**—These are instruments for describing circles. There are several varieties ; only a few of the more generally useful, however, are described here. The commonest form is that known as a "half set," Fig. 15, which consists of a pair of legs of which one point is removable, and may be replaced by a pencil leg or "point," or by a pen or "ink point," *c*, Fig. 15, as they are termed in catalogues and a "lengthening bar," *a*, Fig. 15, this last is inserted into the socket of the compasses and the pen or pencil point inserted into the other end of the bar, for describing circles of large radius. Some instruments are fitted with movable needle points. These are too fragile for the inexperienced student's use and should be avoided ; so also should those compasses having triangular "points," which make large holes in the paper and are difficult to set accurately. Round hard steel points fixed into the legs are the best, as shown at *b*, Fig. 15, and there should be a joint in the socket leg to enable the pen point to be set perpendicularly in the paper when the legs are opened out widely ; preferably there should be a joint in each leg, as this considerably increases the working "span." The usual sizes of these instruments are 4½ in., 5 in. and 6 in. long. When only a half set can be purchased, and the small instruments mentioned subsequently are not obtained until advanced work is attempted, the medium-size set will be found the most serviceable, but if complete equipment is obtained at the start, choose the largest size in compasses and smallest in dividers and spring bow.

In choosing compasses perhaps the chief point to note is the fit of the joints ; the legs should move "sweetly," without any jerk. Socketed joints should slide together tightly without shake throughout ; and all joints should have screwed, not riveted pivots.

**Dividers.**—These are compasses with solid or non-removable legs ; they are used for taking and transferring dimensions, for stepping off series of equal dimensions, and —as their name suggests—for dividing dimensions, etc., into various numbers of parts by trial.

For advanced work a variety termed "hair spring" is to be preferred. These have the point of one leg attached to a spring controlled by a small milled head screw. The coarse adjustment is made in the usual way by pressure of the finger on the legs, then very minute final adjustment is made by turning the screw-head.

**Bow Compasses**, Fig. 16.—These are smaller and lighter than the full-size instruments. They are made in sets of three, having fixed pen, pencil and divider points, and are of two sizes, 3 in. and 3¾ in. long. These are very convenient for describing smaller circles and curves.

**Bow-Springs**, Fig. 17, are miniature compasses also made in sets of three. The legs are formed of spring steel and are normally open to their greatest radius about ⅞ in., but may be closed by turning the milled head screw to describe circles down to $\frac{1}{16}$ in. radius. They are usually sold in sets in velvet-lined cases, but single bows are also supplied. They are useful for drawing very small circles and curves.

**The Beam Compasses.**—These are pen and pencil legs, inserted into brass sockets, which are then adjusted upon a lath or rod, called the "beam." They are used for describing circles of greater radius than the compasses will extend. Fig. 18 shows a home-made arrangement in mahogany that will be readily understood upon inspection.

**The Ruling Pen**, or, as it is often miscalled, drawing pen, Fig. 19, for it is quite unsuitable for *drawing* in the usual sense of the term, consists of a pair of adjustable steel nibs fixed to a straight handle. The better sorts have one of the nibs hinged to enable it to be more thoroughly cleaned, and to permit the removal of the burr formed on the edges when resharpening. Its use will be described fully later, and it need only be said here that it is used with a straight or curved ruler for inking-in pencilled lines.

**The Parallel Rule,** Fig. 20, is an instrument for drawing one line parallel with another, to which one edge of the rule is applied. It is of rather limited use, and requires considerable care in manipulation. It is superseded for students' use by the pair of set squares as described on page 25.

**Protractors.**—These are instruments for measuring and setting out angles. There are two forms, the circular or semicircular, and the rectangular. They are made of

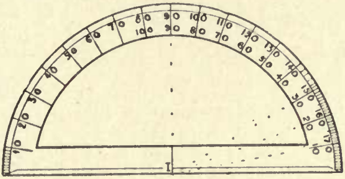


Fig. 1. Semicircular Protractor

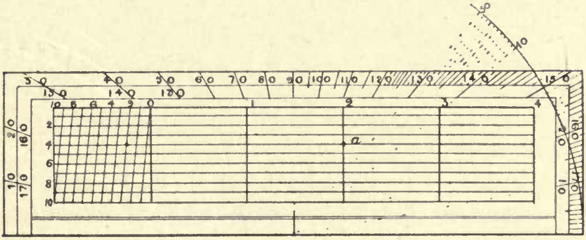


Fig. 2. Rectangular Protractor and Scale

various materials—boxwood, ivory, bone, brass, etc. Although differing greatly in appearance, the two forms are set out or divided in exactly the same manner, as will be seen by inspection of Fig. 2, whereon a part of the describing semicircle is shown, with the divisions radiating from the centre, a few of these are dotted-in in each figure to indicate the principle of dividing the instrument, which may be briefly explained thus: A circle of any diameter is divided upon its circumference into 360 equal parts, lines are drawn from these points to the centre, and each division thus formed is said to contain one degree, and, obviously, any other circle described upon the same centre will be divided into the same number of degrees by these radiating lines, therefore it does not matter what *size* circle or protractor is used, the number of degrees contained between any two lines forming an angle will be accurately shown by it, and on the instrument these are numbered for easy reference, commencing at the diameter of the circle: in the example only each tenth degree is numbered, and a few of the intermediate degrees shown (note, degrees are usually indicated by a small circle over the figure thus, 30°). The semicircular instrument contains only half of 360°—viz. 180°. For convenience of reference the degrees are numbered from 1 to 180, in both directions, that they may be read off readily from either hand. Upon the straight edge of the semicircular and the plain edge of the rectangular protractor in the middle of its length, is placed an index mark which indicates the centre of the circumscribing circle. When it is desired to measure an angle, the instrument is laid with its edge upon one side of the angle, and the aforesaid centre mark at the vertex or intersection of the sides, then the number of degrees contained between the two sides of the angle, will be indicated on the edge of the protractor where the second side intersects it. In like manner an angle is laid off on any given line by placing the straight edge of the protractor on the line, ticking off the required angle close to the edge, marking the central or index point, and drawing the second side between the two points marked. The scale shown in the middle of Fig. 2 is explained under Scales, page 22.

## MISCELLANEOUS DRAWING ACCESSORIES

**Drawing Paper.**—Of this there are several kinds; for elementary work "cartridge" paper is the most suitable, but a smooth or nearly smooth surfaced kind should be chosen. A rough-surfaced or coarse-grained paper causes the point of the pencil or pen to wear down quickly, and the production of lines of a regular depth or thickness becomes, if not an impossibility, a work of great difficulty. Paper should be purchased from dealers in artists' materials, and, if unobtainable locally, may be ordered by post from well-known houses such as Reeves & Sons, Moorgate Street; Rowney & Son, Oxford Street, w.; Winsor & Newton, Newman Street, w.; B. J. Hall & Co., Victoria Street, s.w.; all of London, who will supply quires of twenty-four sheets or single sheets at slightly increased prices. For advanced work, or important drawings that will have a deal of handling, a superior quality of paper, called hand-made, is advised. These are known by their various makers' names, such as Whatmans', Harding's, Hollingsworth's, Turkey Mill, etc. Hand-made papers are of varying grades, according to their smoothness of surface; those most frequently used are: H.P., "hot-pressed"—the smoothest, best for inked line drawings, but taking colour only moderately well; N., signifying natural grain—not hot-pressed, sometimes described as "Not"—slightly rough surface, the ordinary article for general use; and R. "Rough"—good for colouring upon, but practically useless for fine or mechanical drawing.

The standard sizes of drawing paper most used are: royal, 25 in. × 20 in.; imperial, 30 in. × 22 in., and double elephant, 40 in., × 27 in. Of these the most economical size is "imperial," which may be cut into halves to form half imperial, 22 in. × 15 in., a very convenient size for elementary practice.

**Drawing Pencils** are made of about twelve degrees of hardness, but practically only four are in general use by architectural draughtsmen and students, indicated by the letters F, H, HB and B. The choice of these must be left to the individual, as they must be selected according to the "touch" of the draughtsman. Beginners may well start with H and HB, the first for "pointing off" dimensions, construction lines, etc.; the second for "lining-in" or finishing the drawing when it is not intended to ink it. B is serviceable for shading and freehand work, but as the various makers' " degrees " differ, the selection should be made by experiment. When a suitable pencil is found, the same brand should be adhered to always. It may be added that no pencil sold for less than a penny need be expected to give satisfactory work, and higher priced ones are cheaper in the end, as they last longer. The hexagon shape, *a*, Fig. 1, page 26, is the best to use, as it will not roll off the sloping board. Special small pencils are made to fit various compasses ; but the author personally prefers to split down a piece of ordinary size pencil and extract the lead, which is then rolled up in a strip of paper, pasted or gummed until the right size is obtained to fit the holder. These " paper " pencils are easier to keep in order than the wood-cased ones, and the same depth of tone can be obtained in the curves as in the other parts of the drawing. The best way to sharpen these is to wrap a narrow strip of fine glass paper around the point, then revolve the pencil between the thumb and finger.

**Rubber** is used for erasing pencil lines ; only a " soft " kind should be used, so that the surface of the paper is not destroyed. Square blocks are used for extensive alterations and cleaning, and wedge-shaped pieces for small erasures. On no account should a hard rubber, or so-called " ink eraser," be used, as this destroys the surface of the paper, so spoiling the appearance of the drawing. Drawing that requires considerable cleaning should be rubbed over with slightly stale or dry bread crumb, the palm of the hand being used for the purpose.

**Drawing Pins,** Fig. 21, p. 11.—These are used for securing the paper to the board ; medium sizes are the best, and those with domed or bevelled heads which allow the **T**-square to pass over them without catching. The perfect drawing pin, however, has yet to be invented. Most of those in use are injurious either to the paper, the board or the finger nails, also to the temper of the user.

The pin lift, Fig. 22, page 11, is useful for extracting stubborn pins.

**Ink.**—The ink used in architectural drawing is a special kind that will not corrode the instruments. It is usually called Indian ink, but is really made in China (that is, the genuine). This requires to be rubbed up in water in a saucer—the bottom of an ordinary tea saucer can be utilised if the proper one is not at hand—it is rubbed up similarly to cake colours.

Only sufficient for use at the time should be mixed, as it dries quickly and becomes gritty if remoistened after drying in the saucer. A little indigo either from the domestic " blue " bag or artists' water-colour mixed in the liquid improves and intensifies the black. Various liquid " Indian " and waterproof inks in bottles are now prepared and stocked by dealers; these are convenient when much inking-in has to be done. They are also useful for drawings that have to be coloured, as this kind of ink will not wash up, but it is rather difficult to use in fine pens, as it dries rapidly and clogs the pen, which requires constant cleaning or replacing. The author keeps a phial of water at hand, into which the pen can be dipped occasionally.

**Tracing Paper and Cloth.**—This is specially prepared paper or linen which is semi-transparent. When placed over a drawing, the lines, etc., can be seen through it, and easily copied or "traced" with pencil or pen. It is supplied in sheets 20 in. × 30 in. and 30 in. × 40 in., also in rolls of various widths and about 21 yards long.

**Scales** are instruments of wood, metal, cardboard, etc., having one or more faces, upon which are engraved or printed a number of equal divisions and subdivisions, which may represent yards, feet, inches, etc., as determined. They are used to set off dimensions upon drawings to any desired reduction in size of the original or object represented.

When a drawing is made of the same dimensions as the object it represents it is said to be drawn "full size," when made smaller, it is said to be drawn "to scale." Such a drawing must, if it is to be used again for obtaining accurate measurements of the object, be made proportionately throughout—that is, every part of it must be drawn to the same scale, and it is to ensure this, in technical drawings, that carefully prepared "scales" are used. The majority of scales are made 1 foot long; but, of course, may be of any other length the maker or user chooses, and they may bear from two to a dozen different scales on their faces. For students' drawing purposes, cardboard scales with not more than one scale at each edge are to be preferred, as with these there is less likelihood of mistakes arising through using the wrong scale. It is often necessary to set out a scale upon a drawing, as a suitable one may not be upon the instrument in the possession of the draughtsman, and in important drawings, the scale should always be drawn first upon the paper and worked from, then any alteration in the size of the sheet due to atmospheric conditions will not affect the measurements, as the scale will alter in the same ratio as the drawing, whilst an independent scale might not.

On page 21 are shown five different scales suitable for laying down on drawings and as many different ways of drawing them; these details differ with the taste of the draughtsman. Fig. 1 is a scale of $\frac{1}{4}$ in. to the foot, and is made long enough to measure 12 feet. Anything drawn to this scale would be $\frac{1}{48}$ of the real size of the object represented, because there are forty-eight quarter inches in a foot, and $\frac{1}{48}$ is called the representative fraction of the scale, or, shortly, "the fraction."

Fig. 2 is a scale of $\frac{1}{8}$ in. to a foot; the fraction being $\frac{1}{96}$.

Fig. 3 is $\frac{1}{2}$ in. to the foot, the fraction being $\frac{1}{24}$. Fig. 4 is $1\frac{1}{2}$ in. to the foot or $\frac{1}{8}$ the real size; because there are eight one and a half inches in a foot, and as the representative fraction of this scale is $\frac{1}{8}$, care must be taken when reading instructions not to confuse it with $\frac{1}{8}$ *inch* to a foot. This is a favourite workshop scale, as the common 2-foot rule can be used, calling the $\frac{1}{8}$ in. divisions thereon inches,

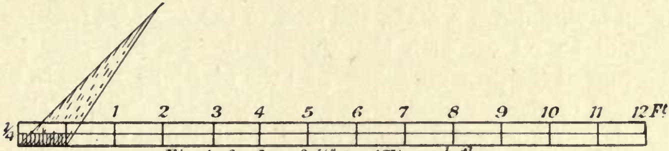

¼
1
2
3
4
5
6
7
8
9
10
11
12Ft

*Fig. 1. Scale of ¼" to 1Ft or $\frac{1}{48}$th*

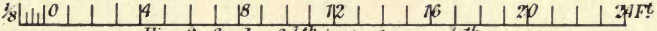

⅛
0
4
8
12
16
20
24Ft

*Fig. 2. Scale of ⅛th in to foot or $\frac{1}{96}$th*

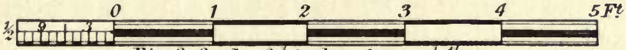

½
0
1
2
3
4
5Ft
6
3

*Fig. 3. Scale of ½ inch to foot or $\frac{1}{24}$th*

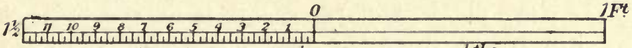

1½
0
1Ft
11
10
9
8
7
6
5
4
3
2
1

*Fig. 4. Scale of 1½ inch to foot or $\frac{1}{8}$th*

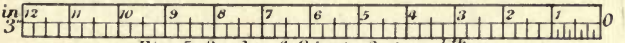

in
3"
12
11
10
9
8
7
6
5
4
3
2
1
0

*Fig. 5. Scale of 3 in. to foot or $\frac{1}{4}$th*

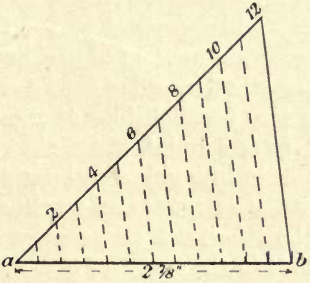

a
b
2
4
6
8
10
12
2 ⅞"

*Fig 6.*

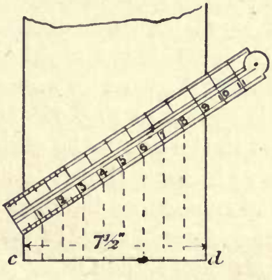

c
d
7½"
1
2
3
4
5
6
7
8
9
10
11

*Fig. 7.*

Figs. 1 to 5. Architectural Scales. Fig. 6. Method of dividing a Scale.
Fig. 7. Workshop Method of dividing a Line into Equal Parts

and each 1½ in. a foot. Fig. 5 is a scale of 3 in. to 1 ft. or one-fourth full size; the representative fraction is $\frac{1}{4}$.

The most common scales in architects' offices are $\frac{1}{8}$ in., $\frac{1}{2}$ in., 3 in. and full size. Engineers' draughtsmen use these also: $\frac{3}{8}$ in., $\frac{3}{4}$ in. and 1$\frac{1}{2}$ in. to a foot and sometimes 6 in.—*i.e.* half-full size—perhaps the worst possible scale to work to, as it is fruitful of errors.

In laying down a scale, the feet, to the required fraction, should be set off with the dividers upon a line near the bottom of the drawing paper, and the divisions drawn in by the aid of the set square, and numbered towards the right hand, starting at the second division; the first one marked 0, is reserved for inch subdivisions. In the larger scales, these may be set off with the dividers direct; but in the smaller ones, it is better to adopt the method shown in Fig. 1, and enlarged in Fig. 6. Set up a line at any convenient angle from the left extremity of the line to be divided, and, opening the dividers to any convenient space, wider than the required division, step it up the inclined line until twelve (or any other number required) spaces are marked. From the twelfth point, draw a line to the right-hand extremity of the line to be divided, as point *b* in Fig. 6. Next draw a series of parallel lines to this one from the other points, and, where they intersect the horizontal line, erect short perpendiculars, which will represent inches in this case. This is a rapid and accurate method of dividing any line. A favourite workshop method by aid of the 2-foot rule is shown in Fig. 7. Draw two parallel lines at right angles to the line to be divided, as at *c* and *d*, which shows a line 7$\frac{1}{2}$ in. long, that is to be divided into nine equal parts; lay the rule across the lines with the extremity on one line, and the required number upon the other, tick off the inches, with a pencil; then draw parallels to the first two through the points to cut the line *c–d*.

**The Diagonal Scale** shown on the protractor, Fig. 2, p. 15, is used for taking very minute measurements. The one shown will measure to two decimal places, or the hundredth part of one of the large or primary divisions, which may represent inches, feet, yards, chains, etc., as required.

It is constructed by drawing a rectangle whose height is generally, but not necessarily, equal to the length of one of the primary divisions, 1–2–3–4 say one inch, then draw nine parallel lines, dividing the rectangle into ten equal spaces. Divide the left-hand primary at top into ten equal parts; these will, of course, in this case, represent tenths of an inch. Divide the bottom line similarly, and draw lines diagonally from one division at the top to the next one at the bottom. Now the lower end of each line has moved one-tenth of an inch to the left in its passage across the rectangle, and as it is itself divided into ten equal parts, each of these parts, counting from the top, is $\frac{1}{10}$ of $\frac{1}{10}$, or $\frac{1}{100}$ of a primary nearer the left than the one immediately above it. Thus, if it is desired to measure 2·24 in., place the dividers with one leg on the primary 2, on the horizontal line 4 as at *a*, and stretch it out along the line until it reaches diagonal 2, as shown by the dot. Any other decimal part may be found similarly, always reading the units on the vertical lines, the tenths on the diagonal lines and the hundredths on the horizontal lines.

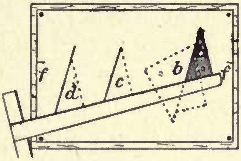
## CHAPTER III

# GENERAL INSTRUCTIONS AND HINTS ON DRAWING

How to Fix the Paper. Finding-Marks—damp-stretching. Using the Squares. To draw Parallel Lines. Sharpening the Pencil. Lining-in. Managing the Ruling Pen. Inking-in. Curved Lines. To keep Drawings Clean. Where to Commence a Drawing—how to proceed. Examinations—how to draw, what to avoid. Laying off Dimensions. To Measure Curved Lines. Managing the Compasses. Locating Centre of Circles. Draughtsmen's Lines and Signs. Sections. Standard List of Material Hatchings

**Fixing the Drawing Paper** for elementary work.—The paper is usually secured to the drawing board by means of drawing pins at the corners (see Fig. 1, page 25). If the paper cockles, on account of its stiffness or through rolling up, fix first a pin at top and bottom edges near the middle, then smooth the paper out with the hand, one side at a time, and pin the corners, thus making it lie quite flat. If it has to be removed from the board before the drawing is finished, a short pencil mark should be made on the paper at each extremity of the edge of the **T**-square, and these marks made to coincide with the edge of the square when refixing. This ensures parallelism in subsequent lines (see *f–f*, Fig. 1, p. 25). Students at technical schools, etc., who may have to use a different board on each evening, should invariably place these "finding marks" on the paper immediately on laying it down. For elaborate drawings, or those that have to be coloured, it is better to damp-stretch the paper; this is accomplished by turning down a margin all round the sheet of about $\frac{3}{8}$ of an inch, then sponging over the remaining portion with clear water until the paper is uniformly damp, when the dry margins are covered with paste or glue, then turned over and rubbed down on the board, where they are left until dry, when the paper will shrink, producing a tight and very smooth surface to work upon. Thick papers are better wetted all over, including the margins, before pasting.

**Method of Using the Squares.**—The T-square must be manipulated with the left hand—that is, it is moved up and down the left edge of the board only. If it is used on more than one edge, and the board should happen to be out of square, all the main lines of the drawing would be wrong. All horizontal lines should be drawn by aid of the T-square and all vertical lines with the set square; this ensures them being perpendicular to each other. (It may be as well here to point out that, geometrically, there is a difference between a vertical and a perpendicular line, though these terms are often used as if they were synonymous. A perpendicular line is one at right angles, or "square" to *any* other line, and obviously may lie in any position on the paper, whilst a vertical line is one at right angles to a horizontal or level line and therefore must be always upright.) If the vertical line to be drawn is longer than the set square, move the T-square up or down as required, keeping the finger and thumb of the right hand on the set square, and blade of the T-square respectively, to prevent lateral movement. Should, however, this occur, the line can be continued unbroken by placing the pencil on the part already drawn, then moving the set square along until its edge touches the pencil, when the line can be continued.

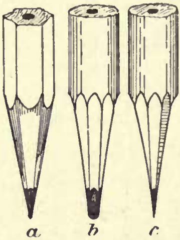


Method of drawing Parallel Lines at any inclination

**Inclined Parallel Lines** may be drawn at any distance apart by placing one edge of a set square to the given line, or at any desired inclination (as at *a*, illustrated above), then bringing a second square close up to another edge, as shown at *b*. The first square may then be moved up or down as required, as shown in dotted lines, when the other two edges will be constantly parallel to their original positions. A more extended range of movement may be obtained by using the edge of the **T**-square as a guide on which to move the set square to its successive positions, as indicated at *c* and *d*, where the full lines represent those to be drawn.

The **T**-square, especially when polished, has an annoying habit of slipping off the sloping board. This may be checked by passing a small rubber band—such as is used for fastening rolls of paper—around the blade near the stock.

**Sharpening Pencils.**—This should be done neatly and carefully with a sharp penknife or chisel; good work can never be done with a blunt or irregularly sharpened pencil. For ruling straight lines a chisel-shaped "point" or edge is advocated by some, similar to *b* and *c*, adjacent Fig. For freehand work, setting off lengths, or for use with French curves, a long conical point should be used as shown at *a*.



Methods of Pointing Pencils

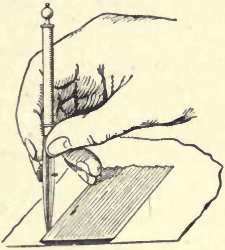
(*a*) Conical Point
(*b*) and (*c*) Chisel Point

*Use the pencil lightly.* Do not "engrave" the paper, nothing looks worse on a drawing than a network of white marks or furrows that once contained pencil lines. It would be a counsel of perfection to advise that *no* false lines should be drawn. These may be looked upon as inevitable with a beginner, but he need not draw undue attention to his errors or tentative attempts.

When a drawing is to be finished in pencil, the preliminary construction may be made with a hard pencil, which will make a faint line, easily removable. After the drawing is complete and found to be correct, remove superfluous ends to the lines, with the rubber, and go carefully over the entire drawing with a softer pencil. This operation is called " lining-in."

**Inking-in.**—If the drawing is to be finished in ink, it is advisable to draw every line first in pencil, and to carry the ends beyond their intersections, as otherwise it is difficult to see where to stop the pen when the ruler lies over the lines. After the inking-in is finished the pencil lines can be removed with soft rubber or bread crumbs.

The method of holding a ruling pen when inking a line is illustrated here. It is, of course, held in the right hand, with the pen upright or nearly so, and the forefinger resting upon the setting screw. The precise height of the hold is, of course, a matter of taste, and is also dependent upon the length of the pen. The pen should have the ink rising about $\frac{3}{8}$ in. between the nib, which must be screwed up until the desired gauge of line is obtained. This should be tried on a spare piece of paper—not the margin of your drawing—and once the pen is set, it should not be altered until all the lines of that depth are finished. Hold the rule or straight edge (which should have a slight under bevel, as shown, to prevent the ink adhering and causing a blot), firmly, with fingers spread out ; this latter seems such an obvious precaution as to be needless to mention, but for the fact that the author has sometimes spoiled a drawing himself by neglecting it. When the draughtsman is intent upon drawing his line correctly, he is apt to relax the pressure with the left hand, then disaster follows swiftly. *Curved lines* other than circular are best inked-in by the aid of French curves, as shown in Fig. 1, p. 28, where the grained portion indicates one end of a " curve," placed so as to coincide with the portion of the line between *a* and *b*, the dotted line indicating the curve reversed to mark in from *c–d*. The connection *b–c* is made at a third adjust-



Method of holding the Ruling Pen

ment, and a fourth adjustment enables the part *d–e* to be drawn, the fully inked line, *a–b–c–d–e,* representing the finished line obtained.

In joining circular to straight lines it is better to draw the circular ones first, and connect the straight ones to them exactly at the springing points as shown at *B*, Fig. 2, on this page. This avoids the unsightly breaks in the continuity of the lines shown at *A*, Fig. 2, in which the straight lines were drawn first.

When removing pencil lines, rub in the direction of the lines, not across them, and clean the rubber of lead, on a piece of coarse linen, frequently.

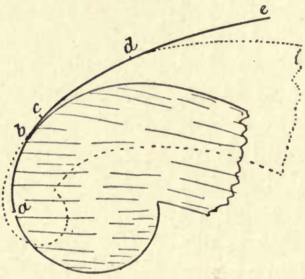


Fig. 1. Method of inking-in Curved Lines

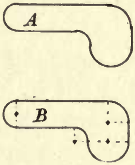


Fig. 2. Right and Wrong methods of joining Straight to Curved Lines

**Keeping the Drawing Clean.**—Beginners always have a difficulty with this. The soiled appearance of their pencilled drawings is due to the squares taking up a little of the blacklead when passing over the lines and depositing it where it is not wanted. To prevent this, wipe them occasionally with a piece of linen and, when lining-in, pass a clean sheet of paper (tissue or tracing paper is best, as it can be seen through) over the parts finished, so that the hand or instruments shall not cause smudging.

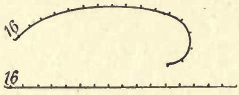
**Where to Commence a Drawing.**—This depends somewhat on the nature of the drawing. When making a number of simple exercises or small separate drawings, commence at top left-hand corner, and work across the sheet horizontally, then work downwards. This avoids continually going over the finished work with the squares. In copying from examples such as are given in this book, or in designing original work, plans should be drawn first, then sections, and finally the elevations projected from the two former.

Do not fill in all the details or hatch sections as you go in any one part of a set of drawings, but get in the chief members, etc., first, in each of them ; this will localise many of the interior lines and prevent overrunning, also, in case of alterations, will save much time.

In making **drawings at examinations** where speed is essential, position on the sheet is not of much moment, but the solution should be commenced by putting in the skeleton or outline of the problem as indicated in the question, and filling in such details as suggest themselves, and as time permits. Always avoid repeating exactly similar parts and confine your attention to important constructive features, rather than minute details. For example, if asked to draw a partition, do not spend two-thirds of the time carefully spacing and drawing in a series of studs, all of which are exactly alike, but draw in all the main timbers first, or even half of them if the two sides are alike, finally putting in a few studs to inform the examiner that you know they should be there. Again, if you are drawing a ledge door it is more important to show the proper position of the braces than it is to indicate nail-heads in the ledges. The examiner will assume you know that the door is to be nailed together if you show him that you know how the members are arranged.

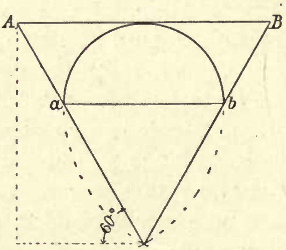
In **Laying Off Dimensions** it is better to use scales than dividers, but if the latter are used do not prick holes in the paper with them—this spoils the appearance of any drawing—but lay the dividers sideways to the line, and tick off their points with the pencil. Do not lay off dimensions from one another successively, but measure from a common point either at the end or middle of the line or member. In the first method an error at one point is repeated throughout, whilst in the second it is confined to the original point and is readily located.

**Measuring Curved Lines.**—It is often necessary to do this with accuracy when a stretch-out or development of the surface is required. The best method is to set the spring bow dividers with a small opening, varying with the quickness of the curve, and stepping it along the curved line, counting how many steps are required to reach from end to end, then transferring to a straight line a like number of steps. It is not necessary to divide the curve exactly into equal parts. If the last step overpasses the end, mark where it reaches and lay off the same number of steps on the straight, then come back and set the dividers exactly to the space exceeded, and mark this within the last mark or step (see Fig. above, where the straight line contains the sixteen divisions of the curved line).



Method of obtaining the Length of a Curved Line

**The Stretch-Out** of a semicircle may be approximately obtained by drawing lines through the ends of the diameter at an angle of 60° with the same, as shown. The set square may be utilised as indicated by dotted lines, then drawing a line tangent to the curve and parallel to the diameter as *A–B* which will be very nearly the length of the curved line.



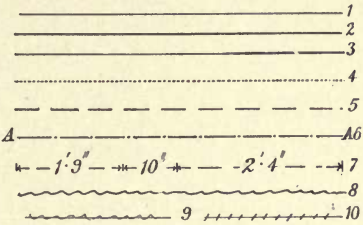
Obtaining Length of a Semi-Circle

**When describing Circles** with the compasses, hold the instrument lightly between finger and thumb as near the top as possible, to avoid closing the legs and revolve steadily, to avoid piercing the paper. If a number of concentric circles have to be described make a cross on a thin piece of card and mark similar crossed lines on the drawing. Make the two sets of lines coincide.

This will locate the centre, and the compasses may be used on the card without damaging the drawing.

A piece of celluloid is sometimes used instead of the card, as the centre can be seen through it. Describe the smallest circles first, as revolving the compass at an angle when opened wide enlarges the hole.

**Draughtsmen's Lines and Signs.**—It is desirable for the benefit of those having to read drawings that a simple and uniform system of lines should be used in preparing them—that is, for example, a dotted line should not be used in one drawing where a full line would be used in others.



Lines and Signs used by Draughtsmen

From an inspection of a quantity of work turned out by leading draughtsmen I conclude that the following list most nearly represents prevailing practice.

**The Fine Line** (No. 1) is used for all interior and inferior ines in a drawing.

**The Full or Heavy Line** (No. 2) for outlines or boundaries. Note, the line should be of a regular thickness throughout, the extent of which will depend upon the scale of the drawing, and it should *not* be as shown in No. 3, uneven and irregular.

**The Dotted Line** (No. 4) for hidden parts, or parts out of the plane of section upon which the drawing is made.

**The Chain or Break Line** (No 5) is generally used to indicate a proposed new position in the object which is shown in full line, or vice versa ; it is also used in lieu of dotted lines where the latter might be confused with projectors.

Projectors are always dotted when left upon a drawing, which occurs seldom, except for teaching purposes. In ordinary work they are rubbed out after the inking-in is completed.

**The Dot and Dash Line** (No. 6) is invariably used to indicate line of section, accompanied by a capital letter at each extremity for reference. It is also used with an abbreviated dash, for paths of a moving portion, such as a door.

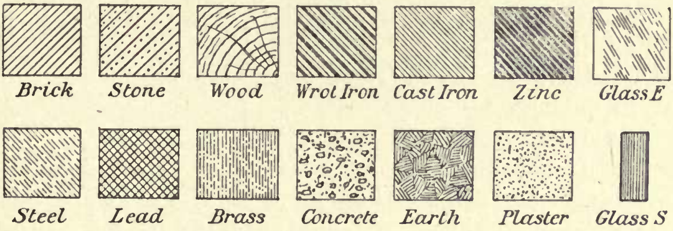
**Dimension Lines** (No. 7) are, as their name indicates, intended to guide the eye along the route of a dimension. They are a variety of the break line with longer intervals and shorter dashes, the object being to make them as unobtrusive as possible, subject to their ready indication of the extremities of the dimension located by arrow heads. Usually in architectural drawings they are made in blue ink and centre lines are made in red.

**The Broken or Irregular Line** (No. 8) is used to indicate that the drawing or part on which it occurs is much longer or wider than is shown, the real dimension being specified in figures. The object of so breaking a drawing is to curtail its space, and is a common practice in preparing " rods " or other full-size drawings in so far as widths are concerned. Upon rods, the length is never broken; to do so would render the rod useless for setting-out from.

**The False Line** (No. 9) is, as shown, " false " in two senses, as both the line to be removed and the indicated line should rightly be in pencil, which, of course, is impossible in a printed example. When making a drawing of any importance a number of tentative lines may be necessary; again, the inexperienced draughtsman will place lines where he does not intend them. It is not always the best thing to erase these at once. Quite frequently they may be utilised, and constant use of the rubber damages the paper, so, when a false line is made in pencil which is not intended to be inked-in, the draughtsman does not rub it out at once, but " scribbles " it out, as shown, only in pencil; and all vanishes with the final cleaning-off.

Sometimes it is found necessary to dot a line which it was first intended to draw full. In this case do not rub it out, but " herring bone " it as shown in No. 10, of course again in pencil only.

**Sectioning or Hatching.**—The method of indicating various materials by special hatchings is again coming into use by the professional draughtsman, in consequence of the facility with which uncoloured line drawings may be reproduced by the various sun-printing and other processes. When, however, only one or a few copies are required, the drawings are much clearer to read if the various materials are distinguished by colouring the sections, but as it is of little service describing colours without reproducing them, these instructions are confined to black-ink sectioning. The chief conventional hatchings are shown and described above.



Hatchings for Materials

It must be understood that these various hatchings are to be applied to parts in " section " only. " Graining," to indicate wood in elevation, should be indulged in very sparingly; its copious use indicates the amateur draughtsman who thus hopes to hide his faults of design or construction. Technical drawings are not intended to be pictures, and they should indicate their meaning clearly, definitely and economically. A few deft touches with the pen to indicate direction of the grain or to distinguish wood from space is all that is permissible or desirable.

## TECHNICAL DRAUGHTSMEN'S STANDARD LIST OF MATERIAL HATCHINGS (see Page 33)

**Brick.**—Medium ruled lines at an angle of 45° with chief dimensions, not too closely drawn.

**Stone.**—Similar lines alternately with dotted or broken lines.

**Wood.**—Lines slightly curved drawn freehand, representing the annual rings. Large timbers are indicated by a few radiating "shakes." Adjacent pieces should be distinguished by drawing the lines in reverse directions.

**Wrought Iron.**—Alternate thick and thin lines ruled at an angle of 45°.

**Cast Iron.**—Closely ruled lines at angle of 45° with main dimension.

**Steel.**—Broken fine lines at 45°.

**Lead.**—Reversed medium lines or "cross hatching."

**Brass.**—Dot and dash lines perpendicular to longest side.

**Zinc.**—Heavy black ruled lines at 45° to longest direction.

**Glass.**—Longitudinal ruled fine lines.

**Glass in Elevation.**—Diagonal ruled lines, lightened or erased with the rubber irregularly to give effect of broken light.

**Concrete.**—Irregular curved shapes and dashes.

**Earth.**—Interlaced cross hatching in patches.

**Plaster.**—Points of ink or splashes.

**Small Sections in Metal**, when it is not desired to indicate any special kind, are put in solid black.

## CHAPTER IV

## LETTERING DRAWINGS

Objects and Requirements in Lettering. Faults the Beginner should avoid. The Relative Sizes for Titles. The chief Types of Letters. Names and Characteristics — Roman, Stone, Block, Italics, Egyptian, Stump. Numerals. Alphabets. Details of Lettering—necessity of uniform size, how to obtain it. The Proper Slope. Balance—how to ensure it. Proportion of Letters. Spacing—its difficulties. What to aim at to obtain Uniformity. Optical Corrections. Points of Detail. Right and wrong methods of forming Letters. Tools to use

THE proper lettering of technical drawings is a matter of almost equal importance with the preparation of the drawings themselves. By the term " lettering " is meant the writing in of titles, reference notes, numerals, directions, etc., upon drawings.

Various other terms have been used to describe this operation, including titling, writing, printing, noting, etc. None of these seem correctly or comprehensively to describe the operation. " Lettering " would appear to come nearest to an accurate definition, as we must first form letters before we can obtain words.

Letters and alphabets have, in their fundamental characteristics, a conventional or orthodox form which it is not wise to depart from too widely. It may be taken for granted that the object aimed at in lettering drawings is to make the drawing plainer or more understandable to the reader, and anything that detracts from this object is obviously out of place, however artistically interesting or curious it may be in itself.

A certain amount of freedom and individuality of *style* is not only allowable but is desirable, and adds to the beauty and interest of a drawing, but beginners especially, should guard against a tendency to produce grotesque caricatures of letters, under the mistaken idea that unfamiliar shapes are necessarily artistic. Before one can "invent" new designs in letters, the history of their evolution or development must be studied, when it will be found that there is a reason for the shapes, characteristics and proportions that have become conventionalised.

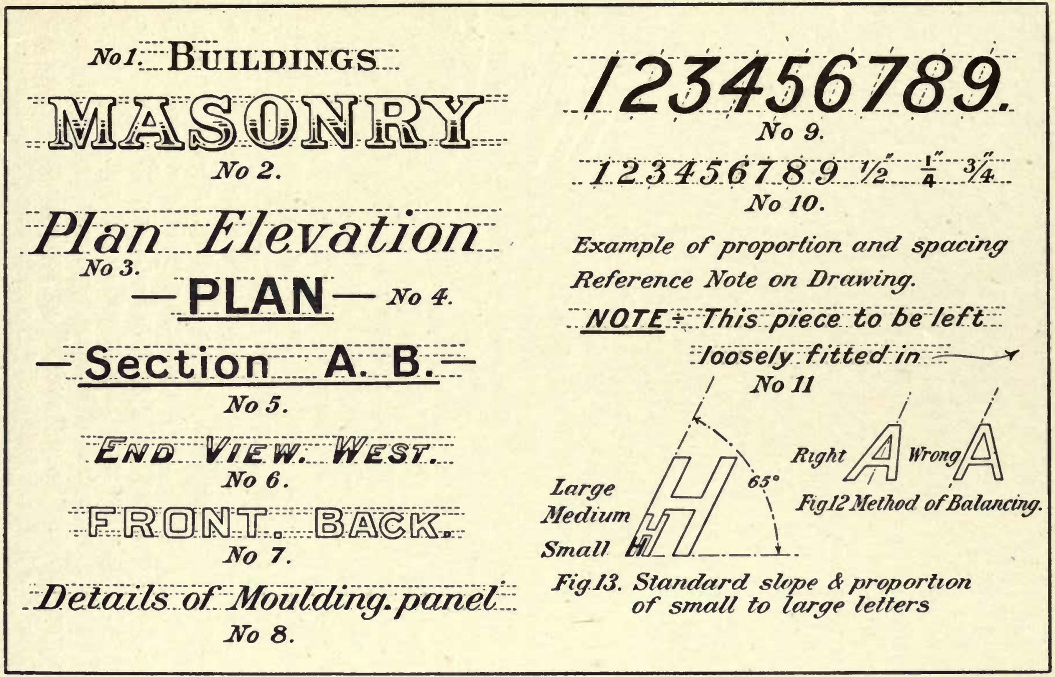
This is not the place to consider the evolution of alphabets with a view to their improvement. We must be satisfied with providing a suitable type of lettering for technical drawings, as adopted by expert draughtsmen in the best architectural and engineering offices at the present time, and to describe the readiest and most workmanlike methods of producing them.

The beginner would do well to confine himself to one or other of the alternative examples given, and to acquire a thorough mastery of the particular type chosen before attempting to produce a style of his own.

It will be as well to remember that, whilst ugly, careless, illegible lettering will spoil the appearance of the best and most accurate drawing, a badly executed drawing is made no more acceptable by being well lettered.

The characteristics of the style chosen should be noted, and the common fault of using two or more different styles in the same word or line should be avoided. For instance, it would be wrong to use the "a" of No. 3, page 37, with the styles shown in Nos. 11 and 13, or say, the "e" of No. 5 with type No. 8

The use of many types or even different sizes of the same type of letter on a drawing is to be deprecated, as conveying a sense of unrest to the observer. Good draughtsmen usually content themselves with three, or, at the most, four, sizes of letters upon one drawing: "large" for the main heading, "medium" for sub-titles and "small" for details. When a note calling special attention to some particular part is required, a special type is used, quite different from


No 1. BUILDINGS
MASONRY
No 2.
Plan Elevation
No 3.
—PLAN— No 4.
—Section A. B.—
No 5.
END VIEW. WEST.
No 6.
FRONT. BACK.
No 7.
Details of Moulding. panel.
No 8.
123456789.
No 9.
123456789 ½" ¼" ¾"
No 10.
Example of proportion and spacing
Reference Note on Drawing.
NOTE:- This piece to be left
loosely fitted in
No 11
Large
Medium
Small
65°
Right
Wrong
Fig 12 Method of Balancing.
Fig 13. Standard slope & proportion of small to large letters

Types of Lettering for Technical Drawing the rest, as shown at No. 11, page 37. The terms "large," "medium" and "small" are, of course, purely relative, and not indicative of the size (see Fig. 13, page 37). The actual sizes of the letters chosen must depend upon the size of the drawing or its scale, and no hard and fast rule can be given for this, as so much depends on circumstances, but as some guide to the beginner it may be stated that the "heading" No. 2, if made twice the size printed, or say $\frac{1}{2}$ in. high, would be a suitable size for double elephant drawing sheets —*i.e.* 40 in. × 27 in., and No. 7 made $\frac{5}{16}$ in. high would be suitable for headings upon imperial sheets.

Before entering into the details of spacing and the formation of letters, it will be as well to give the technical names of the various types illustrated, and draw attention to their characteristics. It may also be pointed out that the terms used here are those of draughtsmen and lithographers. Printers and sign writers in some cases use different terms; so also do stone and metal engravers. In fact, the nomenclature of alphabets is somewhat chaotic, and it is deemed advisable to adhere to those definitions commonly used by modern technical draughtsmen and map makers.

**Roman** (No. 1).—This example shows two sizes of capitals termed by printers, "upper case" letters, and further defined by them as "caps. and small caps." The terms, "upper case" and "lower case," which are now getting into text-books, are printers, or rather compositors', terms indicating capital type letters and small type letters, and these do not indicate any special style of letter. For convenience of composing, the small letters, which are most frequently required, are placed in a case close to the operator, and those less frequently required—*i.e.* capitals—in a case above; hence the terms, upper and lower case.

The characteristics of Roman type are that the letters are upright, and have "serifs" or projections beyond the limb of the letter. Originally the serif was a fine line used for the purpose of cutting off or squaring the ends of the stroke. Serifs are employed in other types, but in the

Roman they are always joined to the limb by curved lines. The limbs of the curved letters, B, R, S, etc., swell in the middle of the stroke, the up and terminal strokes of the others being fine.

**Stone** (No. 2).—This is a purely modern ornamental letter, shaded on one side, and is technically known as "open"—*i.e.* the limbs are bounded by two fine lines without ink or colour between. If partially filled in with dot and curve as shown it becomes "ornamented open stone." In this type the serif is of substantial proportions.

**Italics** (No. 3).—Also termed sloping Roman. This is one of the easiest types to form with the writing pen. Originally it was the printers' imitation, in type-letters, of handwriting, which is naturally sloping. It was first used by the Italian printers, hence the term, "italics." If these small letters were made upright they would then be termed lower-case Roman.

**Block** (Nos. 4, 6 and 7), also called sanserif—*i.e.* without serifs—is of three varieties: "solid," as No. 4; "open," as No. 7, and "sloping," as No. 6; the latter is shown also with a variation known as "half filled." The essentials of this type are that all the limbs should be of equal thickness and that the various limbs join each other at right or acute angles—*i.e.* they do not flow into each other by easy curves as do the Roman, but join up abruptly. It is a purely mechanical type of letter, but none the less useful on that account.

**Egyptian** (No. 5), also known as black letter, is generally used on technical drawings in conjunction with "block" reference letters, as shown in the example. The ruling of the heavy line below, as shown in Nos. 4 and 5, though now usual in modern offices, is not invariable. It should be confined to more important sub-titles that are desired to "leap to the eye" immediately on inspection. No. 11 is termed "sloping Egyptian." The characteristic of this type is that the letter is made of equal thickness throughout.

**Stump** (No. 8).—This is quite a modern and clean-cut type of lettering not greatly differing from italics, but more nearly approaching cursive or running-hand: its principal characteristic is that each letter, though made in "flowing" style, finishes abruptly without connection with its neighbour, which gives it much distinctness.

The lettering of the plates throughout this book is in "stump."

**The Numerals.**—No. 9 is Egyptian. No. 10, originally termed Arabic, is now frequently called Roman. The real "Roman" type, in which letters are used as figures, is but seldom adopted in the drawing office.

**Details of Lettering.**—It is most essential that the letters in a word or series of words should be of uniform size and accurately in line. This does not imply that each letter shall occupy exactly the same space, for that is obviously impossible if we consider the various shapes of letters, but that letters similar in shape shall be similar in size throughout: and symmetry for the whole group of letters is then obtained by judicious spacing, which is dealt with farther on. Take, for example, the word "Elevation," type No. 3. It will be found by trial with the dividers that, leaving the serifs out of consideration, such letters as *n*, *a*, *e* and *v* are all of one size; so also are *i*, *t* and *l*, but these do not occupy so much space as the former letters. Such letters as *C*, *D*, *G*, *O*, etc., will also be similar in size, but occupying more space than either of the former.

To ensure uniformity in height and alignment, it is necessary to rule lines locating the tops and bottoms of the letters, as shown in the examples by dotted lines; these, of course, will be done in pencil when copying, to be rubbed out after the letters are inked in. There is a school of faddists who decry the ruling of lines or the use of any mechanical aids to accuracy as tending to destroy the "freehand" ability of the draughtsman.

These extremists, however, have few if any disciples among practical draughtsmen ; the waste of time, especially by novices, in obtaining anything like satisfactory results without such assistance, places this absolute freehand method outside practical consideration. A slavish copying, or entire reliance upon set squares and rulers is not here advocated, but judicious use of them as aids to the beginner is recommended. With letters of types No. 2 or No. 7, four guide lines may be used; their object will be obvious upon inspection. Where capitals and small capitals, as in Nos. 1 and 6, or capitals and "lower case" letters, as in Nos. 3–5 and 8 are used, three lines are required. There are so few letters with "tails" that it is seldom necessary to use a line for them; slight irregularity in these is less noticeable than with the tops or rising limbs.

Solid block, as No. 4, and numerals, as Nos. 9 and 10, require two lines only. The choice of upright or sloping letters is mainly one for individual taste, but whichever is adopted, the same style should be adhered to throughout, with numerals to match.

The **slope** or inclination to be given is also largely a matter of taste. Too great an inclination should be avoided, as this conveys the impression that the letters are falling over. Some few draughtsmen use the 60° set square as a guide, but in the author's opinion this gives rather too much leaning, and he suggests 65°, as indicated in Fig. 13, page 37, as more suitable for general work.

**Balance.**—The symmetrical letters, or those with double inclined limbs, as A, V, W, X, Y, Z, and the curved letters, as C, G, O, Q, should have neither limb arranged to the common slope, but a line passing through the middle of the letter should lie in the slope, as indicated in Fig. 12, where the right and wrong method of balancing the letter A is shown, as an example of what to do and what to avoid.

**Proportion.**—It has already been pointed out that the letters as a whole must be made proportionate to the size of the sheet they are to occupy; large letters should be used for main headings or titles; important sub-headings should be of medium size, and details, which may be numerous, should be of a smaller size. The relative size of either of these classes is shown in the diagram, Fig. 13, p. 37. In addition to this some attention must be given to the proportion of parts in the letters; otherwise the result will be either weak and ineffective or simply absurd. The proportions adopted in these examples for the rising limbs of letters, and for the major caps, where two sizes are used, is to divide the total height intended for the letters into three equal parts, allotting two parts to the bodies and minor caps and one part to the rising limb or heads as indicated by the dotted lines, or, in the case of major capitals, carrying these up to the third part.

ABCDEFGHIJKLM
NOPQRSTUVWXYZ
*abcdefghijklmn*
*opqrstuvwxyz*

Typical Alphabets—Roman Capitals, Italic Smalls

The Roman and block letters B, R and S should be larger or heavier at the bottom part, so also should the numerals 3, 5, 6 and 8. The middle bar of the E, F and H should be either at the middle of the height or slightly above it, never below: on the contrary, the cross bar of A and lower bar of P must be below the middle.

**Spacing.**—This is the most difficult part of lettering which the inexperienced draughtsman will have to overcome, and it is with the object of assisting him in this that the most frequently occurring combinations of letters upon architectural drawings have been chosen for examples, in preference to a series of complete alphabets. Two of these latter, however, have been given for reference.

The precise shape of the various letters is of less moment than the preservation of the main characteristics of the type and the judicious arrangement of the respective letters into words. It is impossible to lay down any universal rule for the distance apart of letters, so much depends upon circumstances.

Generally the lettering of architectural and technical drawings is rather closely spaced, whilst that of maps, estate plans and the like are widely spaced, as in the latter it is desirable that the words should indicate the extent of the land, etc., they are placed upon, or refer to. Uniform rather than equal spacing should be aimed at, and this is best obtained by so arranging the letters that the white space or voids between them shall be approximately equal in area. To obtain this uniformity, the letters must be spaced according to their shape. Thus, referring to the word **Masonry**, No. 2 in the example, it will be found that although the letters *appear* to be all at the same distance apart, the O and S, for instance, are actually only half the distance apart that the N and the R are, if measured at the middle. Two letters A placed together would need as close spacing as possible, because the equal and opposite slopes of the adjacent sides leave a relatively large white area between them. The P in type 3 needs closer spacing than a similar R would, because the absence of the lower limb leaves a more prominent void. It will thus be seen that the actual spacing, depending upon the juxtaposition of various letters, and the style of the letters themselves, must be left to the judgment of the draughtsman. A preliminary " sketching in " of the letters faintly is advisable upon the space it is proposed to allot them. This is frequently done by experienced draughtsmen on a spare piece of paper, to judge of the effect before drawing the letters finally in position.

**Points of Detail.**—If the various O's and similar curved letters are closely observed they will be found to project slightly above and below the line of the other letters; this is a necessary optical correction. If they are made exactly to line, they will *appear* to drop or look smaller than the others. This will perhaps be more easily realised if a square of 1 in. side and a circle of 1 in. diameter are drawn side by side and level. In lettering of the italic type, the tops of the t's should be shorter than those of l, d, b, etc., and the f should be made without a dropped tail (see Fig. 1, page 42). It is somewhat difficult for the beginner to decide, when forming letters of the italic and similar types, which to make the heavy limbs in the capitals, such as M, N, W, etc. It must be borne in mind that this type is based upon handwriting or "script," and that in writing with the pen, up strokes are made light to avoid spurting of the ink, and the down strokes heavy to give emphasis to the letter. Now take M for example. In writing this letter we commence at the bottom, carrying the pen up with a light stroke, then down with a heavy one, up again lightly and down with a full stroke. N, in like manner, commences with a light stroke, down or across with a heavy one and finishes up with a light one. All printers' type follows this order of procedure, and letters made with the strong strokes or limbs in reverse order look incongruous and amateurish.

**Tools.**—Small and medium-size letters can be satisfactorily executed with a quill or an ordinary J pen. For very small lettering a Gillot's mapping pen is useful. For larger work a writer's brush is advisable; a "Sable" No. 1 would be suitable. As a matter of fact, all the letters given in the examples were done with the brush in the original. Compasses and ruling pen may be used by beginners for block lettering, but of course it can be done much more quickly with the brush. If this is used, the letters should be carefully pencilled in first, then gone over with the brush. Indian ink with a very little Prussian blue rubbed up in it is the best medium to work in, though for reproduction purposes one of the liquid " carbon " inks is generally used, as giving a more intense black. Ordinary writing ink should on no account be used, as it is too fluid to give sufficient depth of tone. A cardboard set square cut to the required " pitch " will be found useful for setting out the sloping letters.

## CHAPTER V

# ORTHOGRAPHIC PROJECTION

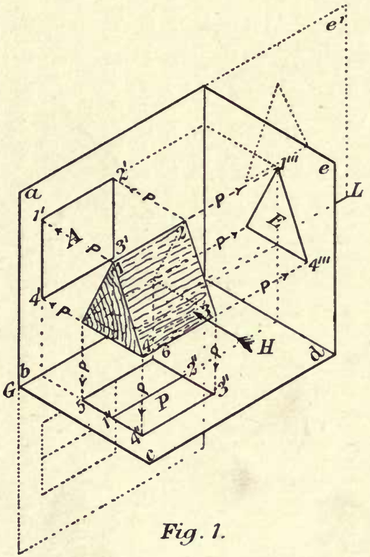
OR

# PRODUCTION OF PLANS, ELEVATIONS AND SECTIONS

Scope of the Chapter—theory of orthographic projection. Projection upon three Planes—Examples. A Dwarf Cupboard—preparation of the plan, projecting the elevation, determining the section. A Field Gate—how to draw it. Types of Roofs—Couple and Couple Close, Collar bolt and tie, King Post; spacing of trusses. A Laminated Rib Roof—details of construction, method of drawing. Doors—framed, ledged and braced, construction of, preparing the drawings. Panelled Doors—how specified. A Diminished Stile Door. Floors—a single floor with details, arrangement of bridgers and trimmers. Windows—Cased Sash frames, common and superior, constructional details, method of drawing. French Casement Frames—details of construction. Shop Fittings—a draper's counter, method of construction. Important points in Technical Drawing. An Octagonal Ogee Roof—dimensions, how to set out the plan, how to obtain moulds for ribs, projecting the elevation. Lantern Lights—definition and description of, an examination question, a solution with details of construction. A Circle-on-Circle Entrance Door and Frame—an unusual form, instructions for projecting the vertical section; obtaining soffit mould, face mould, etc.

IN this chapter it is proposed to instruct the student, by means of graduated examples of various objects drawn from the field of carpentry, joinery, brickwork and masonry, how to prepare plans, elevations, sections and details of construction of several parts of a building and its fittings, thus enabling him to reproduce accurately these copies, as well as more advanced ones that may be contained in other works.

In the first lesson it is assumed that the student knows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c

Fig. 1.

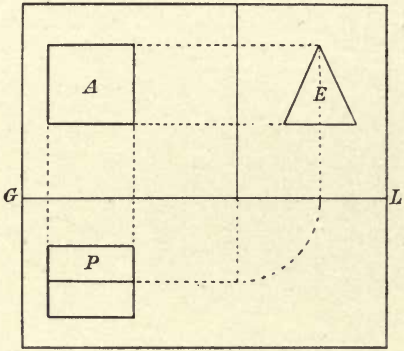


Fig. 2.

Theory of Orthographic Projection

Fig. 1. View of the Co-ordinate Planes in their imaginary relation to the Object. Fig. 2. The Planes developed with Projections of the Object upon them.

nothing further upon the subject than what he has gained by reading the general instructions in Chapter II. In the succeeding lessons the more elementary instructions are not repeated, the notes being confined to new points arising out of the increased difficulties of the examples. Therefore it will be necessary, for a full comprehension of the subject, that the student shall work through the drawings in the order in which they are given. In no case should a drawing be copied to less than twice the size shown, and the more intricate ones should be made to still larger scale.

It will perhaps be advisable, before entering into the actual instructions for copying and producing drawings, to explain briefly, by aid of diagrams, the theory of right-angled projection, usually distinguished as orthographic. This term is derived from the Greek, " orthographia "—*orthos*, correct ; *grapho*, to write—signifying correct writing. In those days the distinction between writing and drawing was not so marked as now, so the word has come to stand for " correctly drawn " in the sense that the drawing is correct as to its dimensions and shape. The word projection is derived from two Latin words, *pro*, forth, and *jacio*, to throw ; so that the literal meaning of " orthographic projection " is a correct view thrown from the object upon a plane surface.

It must also be understood that the " projectors " thrown forth are at right angles or perpendicular to the plane of projection—that is to say, the surface upon which the drawing is made. If otherwise, the resulting drawing might be a " projection," but it would not be an orthographic projection.

To understand this clearly, refer to Fig. 1, page 47. This is a sketch of a triangular block of wood suspended in the air for a purpose that will presently be seen, and arranged with its several edges parallel to three planes which are mutually perpendicular to each other. The planes are further shown in dotted lines unfolded into one plane, but for the moment we will confine our attention to those marked *a–b*, *c–d* and *e*.

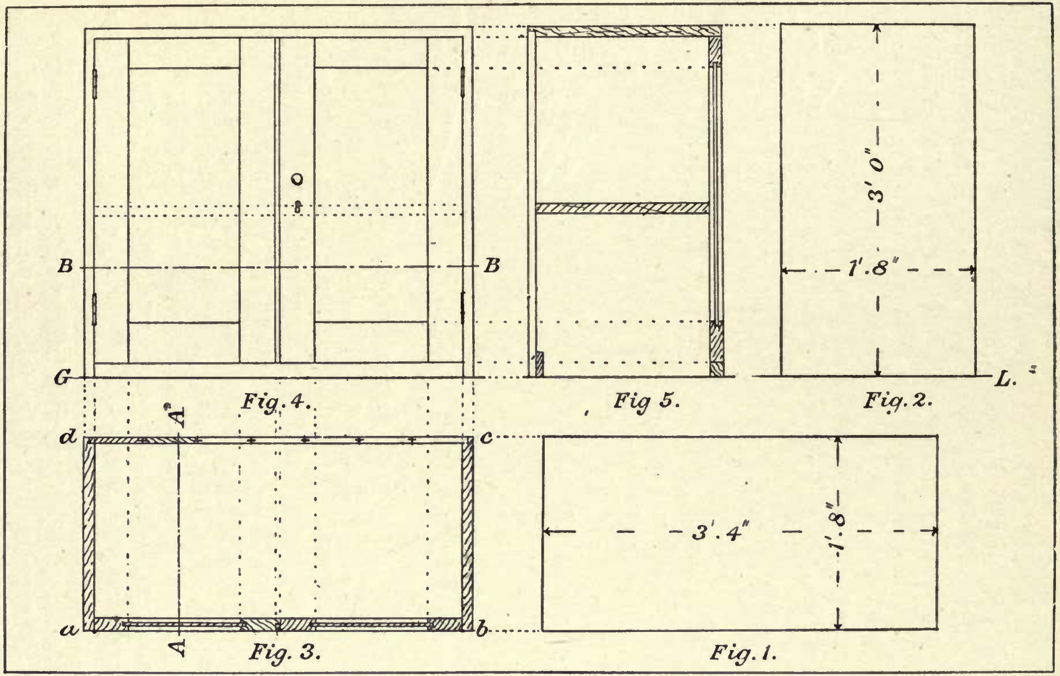
*a–b* is the vertical plane, and *c–d* the horizontal plane; *e* is a special or auxiliary vertical plane perpendicular to the other two, which are known as co-ordinate planes. Now, if we stand exactly in front of the prism, looking in the direction of the arrow *H*, we shall see the side marked 1, 2, 3, 4, but though we know that it is inclined, having the solid before us, we cannot *see* the inclination in this position. What we do see is the exact height measured perpendicularly between the upper and lower edges, also the exact length between the ends, and to obtain this view upon the plane, projectors marked *p* are imagined to shoot forth from each extremity of an edge until they intersect the plane. If these points are joined by straight lines, as at *A*, an "elevation" of the object is obtained upon the vertical plane. In like manner, imagine other projectors shooting forth from the base until they impinge upon the horizontal plane; their points, joined up as at *P*, produce the "plan," or view, we should see if looking straight down from above the object. With these two views we can obtain the correct height and length of the prism, but not the real length of its inclined sides; to obtain these we must use the auxiliary plane which is arranged parallel with the end of the prism. Three projectors shot forth on to this plane as shown will give the shape of the end. This view, *E*, is termed an end elevation. If now we unfold the planes into one surface, as indicated by the dotted lines, we get the three views in their relative positions above and below the ground line *G–L*. Fig. 2 shows the complete plane with the views or projections in correct position, as they appear upon a sheet of drawing paper, and it will be clear that not only can we obtain all the dimensions from these three views, but also the height of the object above the ground (shown at *A*) and its distance from the vertical plane (shown at *E* or *P*). It should be noted that only what is visible upon the surface of the object we are looking at is projected or shown upon the plane behind it. We do not attempt to depict anything that is upon the rear surface. If this is required, auxiliary planes are assumed upon which the required view is projected, though we can, of course, dot upon any view details which are hidden from the eye.

Having now explained the theory of orthographic projection, we will consider the examples given in detail.

**A Dwarf Cupboard**, page 51.—The size of this cupboard is to be 3 ft. 4 in. long, 1 ft. 8 in. wide and 3 ft. in height. The ends, top and shelf are to be 1 in. thick, the framed doors 1¼ in. thick with 3½ in. hanging stiles, 4 in. meeting stiles, 3 in. top rails and 4 in. bottom rails. The bottom rail of front is 1½ in. × 1¼ in., the back rail 2½ in. × ¾ in., and the match-lined back 5½ in. × ¾ in.

We have now all the necessary dimensions, and proceed to lay down the block plan, Fig. 1. In the same relative position on your paper as it is shown in the copy, draw in with the T-square and set square, to any convenient scale, a rectangle 3 ft. 4 in. × 1 ft. 8 in., and a similar rectangle, Fig. 2, to represent the end elevation 3 ft. × 1 ft. 8 in. You will note that there is little to distinguish these but their position. You have just seen that plans are drawn upon, or parallel with, the ground; and elevations at right angles or perpendicular to the same. Now on our sheet of paper, the line marked *G–L* marks the lower limit of ground line for the elevations, and all drawings made above it are in elevation, and all below it in plan.

We next proceed to lay down the details of the cupboard showing its construction, Fig. 3. Draw the lines *a–b* and *d–c*, with the T-square, projecting them from the block plan as shown by the dotted lines; these dotted lines are known as "projectors," and though printed in the copy, will be in pencil only, upon your drawing, to be rubbed out later when the inking-in process is over. Mark off along *a–b* 3 ft. 4 in. to scale, and draw the perpendiculars *a–d*, *b–c*. You will now have an outline on your paper exactly as Fig. 1, and in future work this is all that will be necessary,


B
B
G
L.
Fig. 4.
Fig 5.
Fig. 2.
3' 0"
1'.8"
d
c
a
b
A
A
Fig. 3.
3'.4"
1'.8"
Fig. 1.

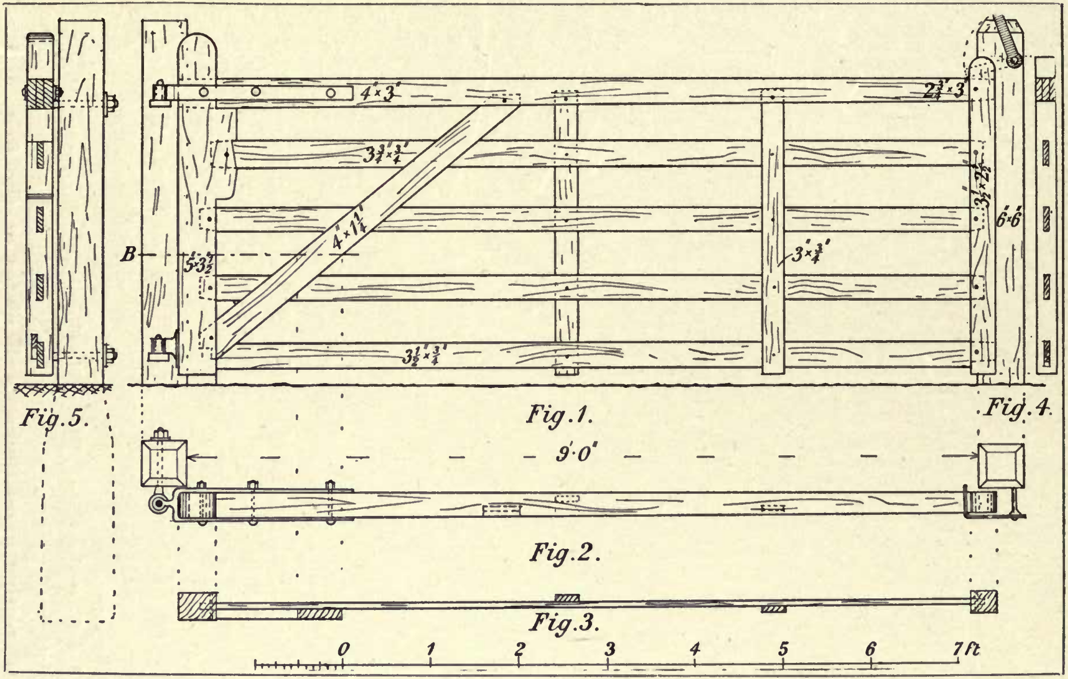
Orthographic Projection—A Dwarf Cupboard

Fig. 1. Block Plan. Fig. 2. End Elevation. Fig. 3. Horizontal Section. Fig. 4. Front Elevation. Fig. 5. Vertical Section

Fig. 1 being superfluous. Next scale off the thickness of the doors, ends and back as given in the specifications, and draw in parallel lines representing the insides ; then set off the stiles. To obtain position of meeting stiles, set off a centre line in the width. This will be 1 ft. 8 in. from either end, the bead is ½ in. wide, so set off ¼ in. on each side of centre line, then 3¾ in. each side, which will be the inner edges of the stiles. Next set off ½ in. within these edges for plough grooves and mark across. Draw the panels in the middle of the thickness ⅜ in. thick. Draw a ½ in. rebate in the ends to receive the back and divide up the width into 5½ in. boards. Indicate the tongues by short lines. This completes what is generally termed the " plan," but which is really a horizontal section which we may assume is taken on the line *B–B*, Fig. 4—That is, if the cupboard existed, and it were cut through with a saw upon the line *B–B*, the appearance at the line of cut would be as shown in Fig. 3. We can next project the front elevation (Fig. 4) from the plan. The dotted lines indicate the direction of these and they will obviously be made with the set square resting upon the T-square, which is held with its top edge just clear of the line *a–b*.

The lines are stopped at a horizontal projector drawn from the top of Fig. 2 as shown. This, of course, locates the top of the cupboard. After drawing the outline, we may scale off the dimensions of the various parts as given in the specification at the commencement, or, as is more usual in practice, proceed at once with the vertical section (Fig. 5) in a similar manner to that prescribed for the horizontal section, and, having obtained the width and thickness of the various parts, we then project them into the elevation, the intersection of the two sets of projectors completing the elevation mechanically.

The above procedure, with trifling variations, will answer for the reproduction of the following examples, and if the student is not clear as to the actual construction of the fitting he is referred to page 95, where an isometric view of the


4"×3"
2¾"×3"
3¾"×¾"
4"×1¼"
B
5"×3½"
3"×¾"
3½"×2½"
6"×6"
3½"×¾"
Fig. 5.
Fig. 1.
Fig. 4.
9'0"
Fig. 2.
Fig. 3.
0
1
2
3
4
5
6
7 ft

A Field Gate

Fig. 1. Elevation. Fig. 2. Plan of Top Bar. Fig. 3. Section at *B*. Fig. 4. Section at Striking Stile. Fig. 5. Elevation of Heel Post

complete cupboard is given. It may be pointed out that the two sections, Figs. 3 and 5, if drawn full size, would constitute a " rod " or working drawing, all that would be necessary for a joiner to " set-out " the cupboard by.

It must also be explained that although for convenience of reference the examples are to some extent arranged in order of trades they are not constructively grouped, as in the author's works on Practical Carpentry and Joinery. Here they are placed in accord with their comparative difficulty of drawing, and a few constructional notes are added to explain the purpose or uses of the objects represented.

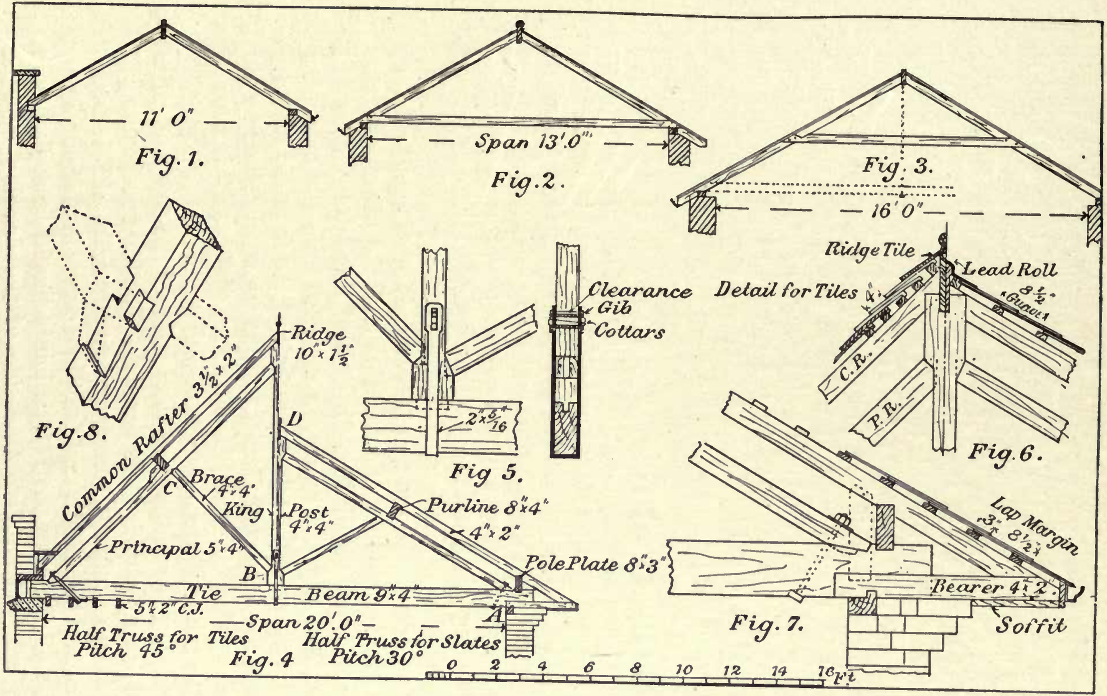
**A Field Gate.**—Not much difficulty will be met with in reproducing this drawing with the copy as a guide, but without it the varying thicknesses of the bars (introduced with a view to reduce the strain upon the heel post and the hinges) offer some difficulty to a beginner.

Lay down the plan first, commencing with the posts ; leave the hinges until last. Next draw in the sections, and, projecting from these, the elevation is readily obtained. Take note that the top bar only, which is thicker than the others, is tenoned through the stiles ; the others are stub tenoned and drawbore pinned, the mortises are made tapering so that the tenon jams tightly as it comes home. The heel post is made thicker than the rest of the gate as all the strain is thrown upon it and the wide bracket is formed on it to stiffen the top bar.

This particular form of gate is chiefly used in Gloucestershire and Wiltshire. Fig. 4 is a section close to striking stile ; Fig. 5 a side elevation of the hanging post with the gate thrown right back.

**Types of Roofs**, page 55.—These are illustrations of the various kinds of roofs used in buildings of comparatively small span.

**The Couple Roof**, Fig. 1, is the simplest construction, consisting of pairs of common rafters spaced about a foot apart, resting upon timber wall plates at the foot, and abutting upon a thin ridge board at the head.


11' 0"
Fig. 1.
Span 13'.0"
Fig. 2.
Fig. 3.
16' 0"
Ridge Tile
Lead Roll
Detail for Tiles
4"
8½"
Gauge
C.R.
P.R.
Fig. 6.
Clearance
Gib
Cottars
2"x5/16"
Fig 5.
Fig. 8.
Ridge
10"x 1½"
Common Rafter 3½"x 2"
D
C
Brace
4"x4"
King
Post
4"x4"
Purline 8"x4"
4"x2"
Principal 5"x4"
B
Tie
Beam 9"x4"
Pole Plate 8"x3"
5"x2" C.J.
A
Span 20'.0"
Half Truss for Tiles
Pitch 45°
Half Truss for Slates
Pitch 30°
Fig. 4
Lap Margin
3" 8½"
Bearer 4"x2"
Soffit
Fig. 7.
0
2
4
6
8
10
12
14
16 Ft

Types of Roofs, with Details

Fig. 1. A Couple Roof. Fig. 2. A Couple Close Roof. Fig. 3. A Collar Tie Roof (with dotted additions—a Collar Bolt and Tie Roof). Fig. 4. A King Post Truss. Fig. 5. Details at *B*, Fig. 4. Fig. 6. Details at *D*. Fig. 7. Details at *A*. Fig. 8. Details at *G*

**The Couple Close Roof**, Fig. 2, has the feet of the rafters tied together by nailing the ceiling joists to them, which strengthens the roof considerably, thus enabling it to be used for wider spans than the previous form.

**The Collar Beam Roof**, Fig. 3, shows the tie or collar placed higher up in the roof, to increase the space in the room below. When this type of roof is used it is necessary to have heavier common rafters than in the preceding types.

**The Collar Bolt and Tie Roof** (illustrated in the same figure) is a form used in wider spans, where the ceiling joists would sag in the middle if unsupported; consequently a light bolt is attached to the ridge and passes through the middle of the joists. Sometimes a plate is fixed across the top of the joists and the bolts are attached to this about four feet apart.

**The King Post Truss**, Fig. 4, consists of a triangular frame fastened together with mortise and tenon joints, which are secured by iron straps or bolts, as shown in the details. These frames or trusses are spaced about 8 to 10 ft. apart, and carry the ridge, purlins and pole plates which support the common rafters and the covering. They also support the ceiling joists, which are either spiked to them or framed into the lower member as shown in Fig. 4.

The drawing shows two half-trusses of different pitches, the one suitable for tile covering and the other for slates (see enlarged detail, Fig. 6). All of these drawings are in elevation, and can be drawn directly, from the examples. The walls should be drawn in first at the required distance apart, then the wall plates, and the common rafters by aid of the 30° set square. Usually 2 in. of "back" is allowed in the rafter above the angle of wall plate.

Having drawn the back line, scale off the depth of rafter and draw the under side parallel. The king post truss will be drawn similarly, commencing with walls and tie beam. Then find the middle and draw in a centre line, about which scale off the king post. The joints should be copied from the enlarged details. One side of the drawing shows a

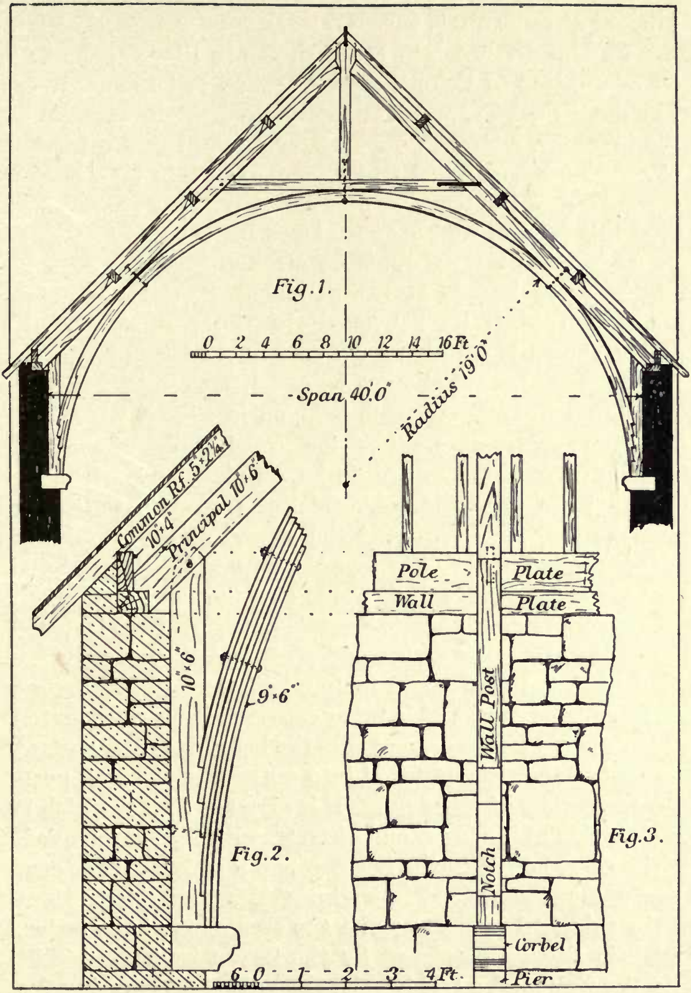


Fig.1.
0 2 4 6 8 10 12 14 16 Ft
Span 40'0"
Radius 19'0"
Common Rf. 5×2¼"
10×4"
Principal 10×6"
10"×6"
9"×6"
Fig.2.
Pole Plate
Wall Plate
Wall Post
Notch
Corbel
Pier
Fig.3.
6 0 1 2 3 4 Ft.

A Laminated Rib Roof

Fig. 1. Cross Section. Fig. 2. Detail at foot of Rib. Fig. 3. Elevation of Fig. 2

parapet finish, the other an eaves finish. Braces should be pitched at same angle as the rafters.

**The Laminated Rib Roof** shown in Fig. 1, page 57 is an adaptation of Colonel Emy's system of laminated ribs. The details are somewhat different from those first used by the inventor, a French engineer who adopted the method of forming large arched ribs by means of thin boards bent around a drum or templet, first about the year 1820. Emy used this form of roof for very large spans up to 60 ft. and 80 ft. In these large roofs he strengthened the arch by adding extra boards at the haunches—that is, to points about two-thirds its height above the springings. The design shown is suitable for a roof of moderate span, the trusses being spaced about 8 ft. apart.

A detail to enlarged scale is given in Fig. 2, which will show the construction. The downward thrust of the arch is taken by corbel stones resting upon piers, and, where the walls are not of considerable thickness, piers or buttresses must be built to counteract the spread of the ribs. The arch is formed of six 1½ in. boards, 6 in. wide, steamed and bent around a drum ; they are left on the same a sufficient time, to take a considerable " set " or curve. Emy fastened the laminæ together with wood pins, and though nails are often used, the pins would undoubtedly be better. Screws are sometimes used, and in other cases the laminæ are bolted all together. In the present case the boards are cut back at the foot of the rib and fitted into notches in the wall post.

A front view of these notches is given in Fig. 3, which is an elevation of the lower end of truss, with the rib removed.

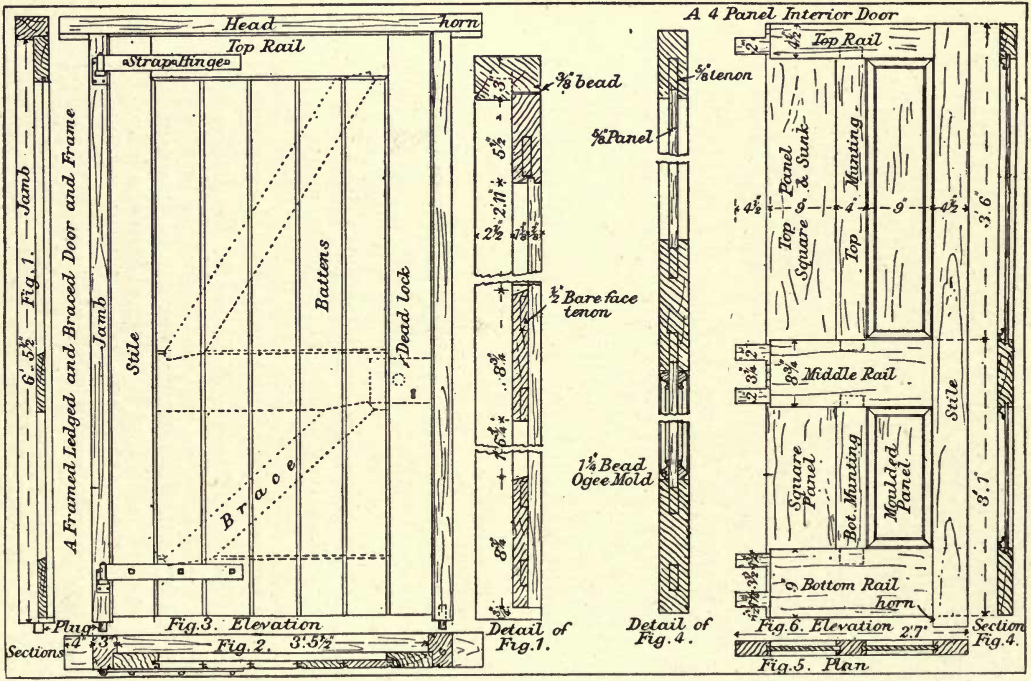
The rib is bolted to the truss, which is of the collar beam type, at three points. The wall post is framed into the foot of the principal rafter to resist the spreading of the latter, which is also counteracted by the heavy wall plate built into the wall, and on which sits the pole plate carrying the feet of the common rafters. These are shown sailing over the eaves, but the finish of these is immaterial ; they might equally well finish behind a parapet.

The collar beam will, unless the roof settles or spreads, be in compression; but, as the latter contingency may possibly occur, it will be better to provide for its becoming a tie beam by tenoning it to the principal rafters and securing these with pins or iron straps.

Not much difficulty will be experienced in making this drawing. Set off the walls to the given span, bisect the span and erect a centre line. Draw the corbels resting on the springing line, and with a radius of 19 ft. describe the soffit of the arch and the back 9 in. farther out. Next draw in the collar beam tangent at the crown, and the two principal rafters at a pitch of 45° tangent to the arch; the remaining lines are parallel to these and can easily be followed from the example. It is a good method in all drawings to get in the most important or essential member first, constructing those of less importance around it as circumstances suggest.

**Doors.**—The framed, ledged and braced door in solid frame shown in Figs. 1 to 3, page 59 is a strong door of the ledge and batten type used for coachhouses, warehouses, etc.

The stiles and top-rail are of equal thickness, in this case 2 in., and are grooved to receive the boards. The middle and bottom rails, termed "ledges," are usually half the thickness of the framing, the remaining half being occupied by the boards or "battens"; these are grooved and tongued together with straight tongues, the two outside boards being rebated and tongued to the frame, as are also the top ends of the remainder. The boards are nailed to the ledges and braces with wrought nails. Braces should rake downwards towards the hanging stile for the purpose of throwing the weight upon the hinges, and be notched into the ledges as shown. The ends should not be taken into the angles, as this has a tendency to push the shoulders off. Barefaced tenons are cut on the ledges, and the top edges of the latter "weathered" to carry off the water. These doors are usually hung with hook and eye straps. The frame is out of 4½ in. × 3 in. deal, solid rebated and beaded; 4 in.


A Framed Ledged and Braced Door and Frame
Head
horn
Top Rail
Strap Hinge
Jamb
Stile
Battens
Brace
Dead lock
Fig. 1.
6'.5½"
Plug
Sections
4"
3"
Fig. 2.
3'.5½"
Fig. 3. Elevation
3/8" bead
3"
5½"
2'.11"
2½"
½" Bare face tenon
8¾"
6¼"
Detail of Fig. 1.
5/8" tenon
5/8" Panel
1¼" Bead Ogee Mold
Detail of Fig. 4.
A 4 Panel Interior Door
Top Rail
Top Panel
Square & Sunk
Top Munting
Middle Rail
Stile
Square Panel
Bot. Munting
Moulded Panel
Bottom Rail
horn
4½
9
4
3'.6"
3'.1"
8¾
3¼
2
9
Fig. 6. Elevation
2'.7"
Fig. 5. Plan
Section Fig. 4.

Doors

Figs. 1 to 3. Projections of a Framed, Ledged and Braced Door in Solid Frame. Figs. 4 to 6. Projections of a Framed and Panelled Door. Figs. 7 and 8. Enlarged Details horns are left on for fixings at the head and $\frac{3}{4}$ in. iron plugs driven in the feet of the jambs for fixing in the stone sill.

Commence with the plan, drawing the stiles of the door first to the given dimensions. Construct the frame around these, drawing the sight lines first, $\frac{1}{2}$ in. within the edges of the door. Divide up the panel equally; next the vertical section at a convenient distance from the boundary of the elevation, the position of which can be seen in the plan. Here, first draw in height and thickness of door, then head of frame, the detail being taken from the enlarged details shown in Fig. 7. Set off the middle ledge 3 ft. $\frac{1}{2}$ in. above the ground and its width $8\frac{3}{4}$ in. down; lift the bottom ledge $\frac{3}{4}$ in. clear of the ground and weather the top edges $\frac{1}{4}$ in. Put in minor details, then project from the two sections into the elevation, starting with the frame and finishing with the hinges.

The four-panel door (Figs. 4-6) is shown with alternative treatment of the panels: on the left, the stile is removed to show the method of forming the tenons, and plain panels are shown; these are described simply as "square panel" or "square both sides." It would be clearer if described as "square and sunk"; the term "square" really refers to the framing which is not moulded, or is left square, the panel is rightly described as sunk to distinguish it from a flush panel with which the framing might also be "square."

The treatment on the right side is usually described as "moulded and square," sometimes as "moulded one side and square sunk." Planted (that is, stuck separately and nailed in) mouldings are always understood, unless "solid" or "stuck" is specified. The student will of course understand that a door will be treated throughout in one or other of the given methods, and not as shown with two methods in one door. When the panels are moulded on both sides, as in the enlarged detail of Fig. 4, it is described as panelled, and moulded both sides, sometimes, as twice moulded.

The instructions for drawing the other door on the same plate will serve also for this one. In drawing the mouldings

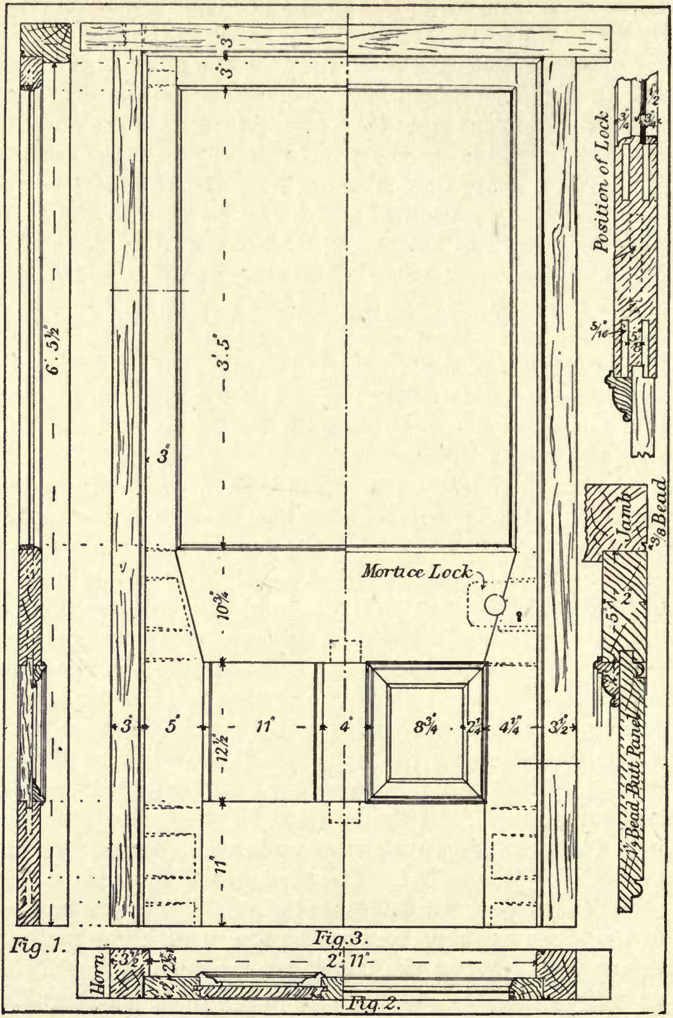


Fig.1.
6' 5½"
3' 3"
3' 5"
3"
10¾"
Mortice Lock
3"
5"
12½"
11"
4"
8¾"
2¼"
4¼"
3½"
11"
Fig.3.
Horn
3½"
2½"
2"
2' 11"
Fig.2.
Position of Lock
¾"
½"
¾"
5/16
5/8
Jamb
3/8 Bead
2"
5/8
¼ Bead-Butt Panel

A Diminished Stile Sashed Door in Solid Frame

Fig. 1. Section. Fig. 2. Half Plans. Fig. 3. Half Elevations. Figs. 4 and 5. Enlarged Details

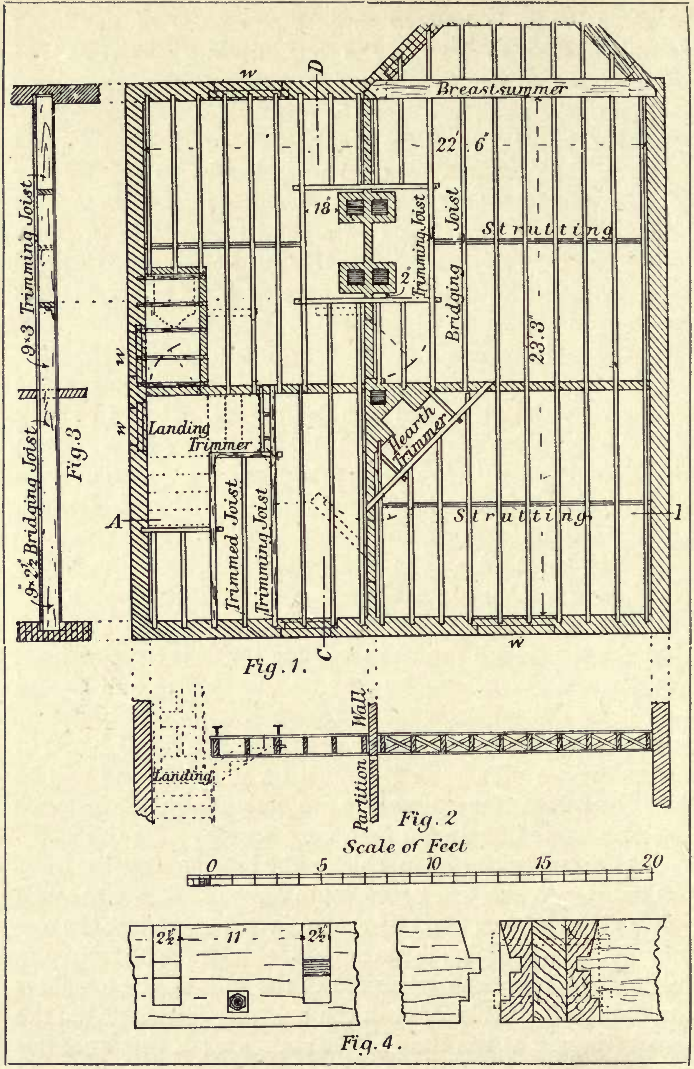
in elevation it is best to project one piece of moulding complete, then to draw in the four mitres with the 45° set square, and to continue the lines around from the intersection of the members with the mitre lines.

**The Diminished Stile Sashed Door** shown on page 62 is a type commonly used in passages to cut off the service apartments from the dwelling-rooms, in which situation it is oftener hung in a solid frame than in jamb linings, and, as the head is usually cut between, instead of built into, the wall, as in the case of outside frames the tenons are shown haunched back.

This door is not essentially more difficult to draw than the previous examples, if care is exercised in projecting the appropriate details to the side dealt with. It will be seen that the elevation shows on one side the back view and upon the other the front view of the door and frame. The plan likewise shows in one half a section, above the middle rail, and the other a section below the middle rail. These sections should be copied from the enlarged details, referring to the small scale section to see the arrangement of the parts.

It will be noticed in the enlarged detail of the back rail that the tenons are shown in full line ; this is for clearness. They cannot, of course, be seen on this section and should rightly be dotted lines.

**Floors.**—A " single " floor suitable for a small house of the suburban villa type is shown on page 64, and will be found an interesting example in projection. In this instance the plan should be drawn first, commencing with the walls, which are one brick or 9 in. thick ; the interior division walls are four and a half brickwork set in cement. Place the wall joists about 1½ ins. clear of the walls and space out the rest equally. The bridging joists are 9 in. × 2½ in. The trimming joists which carry the trimmers at the ends of the openings are half-an-inch thicker than the bridging joists. Note the small trimmer at the head of the staircase ; if this were not used the trimming joist would need to be brought forward and so cause an extra bridger to be used throughout. En-


w
D
Breastsummer
22' 6"
18"
Trimming Joist
Bridging Joist
Strutting
2"
23' 3"
w
w
Landing
Trimmer
Hearth Trimmer
A
B
Trimmed Joist
Trimming Joist
Strutting
w
C
Fig. 1.
9×3 Trimming Joist
9"×2½" Bridging Joist
Fig. 3
Wall
Partition
Landing
Fig. 2
Scale of Feet
0
5
10
15
20
2½"
11"
2½"
Fig. 4.

A Single Floor, with Details

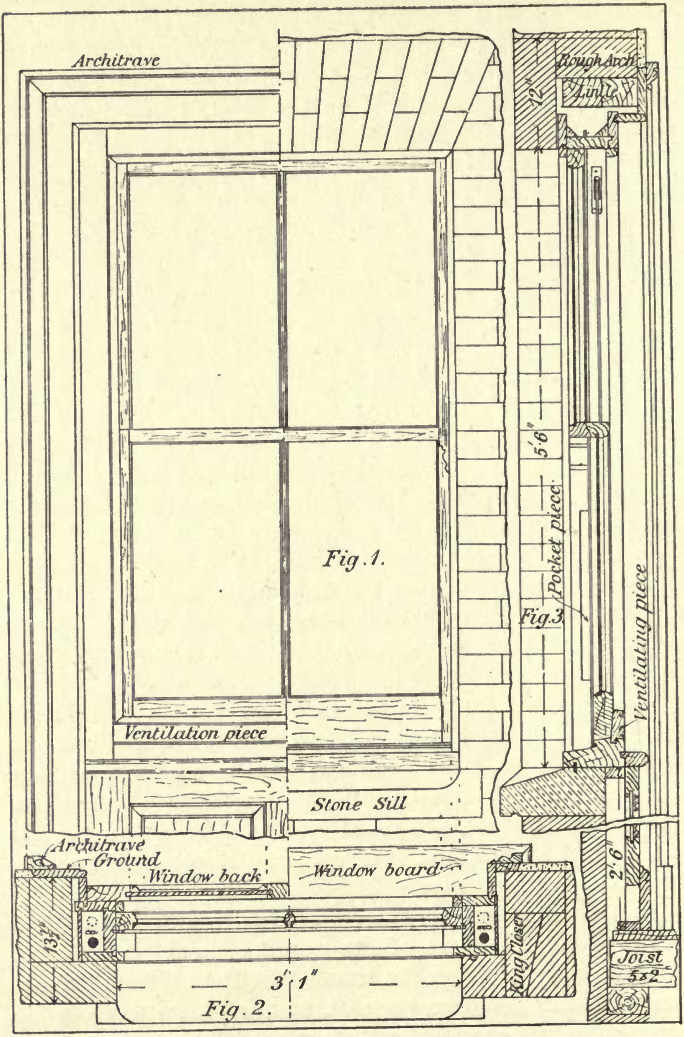
Fig. 1. Plan of Naked Floor. Fig. 2. Section on *A-B*. Fig. 3. Section on *C-D*. Fig. 4. Details of Breastsummer

larged details of the breastsummer carrying the floor across the bay window are given in Fig. 4. This is composed of three 9 in. × 3 in. deals bolted together and stub mortised to receive the tusk tenons on the joists as shown. The transverse sections, Figs. 2 and 3, are projected from the plan on the given section lines.

**Windows.**—A cased sash frame with 2 in. double-hung ovolo moulded sashes is shown on page 66, with enlarged details on page 68. Two methods of construction are given on page 66: the left-hand half-elevation and plan, also the vertical section, Fig. 2, showing the method employed in superior work, all the parts being grooved and tongued together. A framed window back is shown below the sill, with an architrave moulding fixed on moulded grounds and plinth blocks. The section is shown broken for want of space, but the student should re-draw it in full height as figured. The right-hand half-plan and elevation show the construction of a common frame simply nailed together. There is no wood window back in this case; the wall runs straight across under the sill, and is plastered, and a wide window board is used on which the architrave stops. The brick reveals on each side show successive courses.

The superior frame is shown fitted with a ventilation piece or wide bead, tongued to the sill; this allows the bottom sash to be opened for ventilation between the meeting rails without causing a draught at the bottom. In common frames, the usual $\frac{5}{8}$ in. or $\frac{3}{4}$ in. guard bead is made $\frac{1}{8}$ in. wider than the side ones, and is bevelled to enable the sash to clear freely.

**In drawing the frame,** start with the plan, then the section; the sizes of the opening should first be set off from page 66, then the frame "built in" from the enlarged details given on page 68, working inwards from the brickwork. The chief dimensions are: linings, $4\frac{1}{2}$ in. × 1 in.; sashes, 2 in.; pulley stiles and head, $1\frac{1}{4}$ in.; oak sill, 3 in. (twice weathered and throated and three times


Architrave
Rough Arch
Lintle
12"
5'6"
Pocket piece
Fig.3.
Ventilating piece
Fig. 1.
Ventilation piece
Stone Sill
Architrave
Ground
Window back
Window board
13½"
King Closer
3' 1"
Fig. 2.
2'6"
Joist
5x2

A Window Frame and Finishings

Fig. 1. Half inside and half outside Elevations. Fig. 2. Half Plans showing alternative Treatment. Fig. 3. Broken Vertical Section

grooved); parting beads, $\frac{3}{8}$ in.; guard beads, $\frac{3}{4}$ in.; meeting rails, $1\frac{1}{2}$ in. thick; bevel rebated pocket pieces, $1\frac{3}{8}$ in. wide; sashes ovolo moulded, $\frac{3}{4}$ in. × $\frac{1}{4}$ in.

Note that the groove in sill for iron water bar is in line with outside lining (this is often wrongly shown in books in the middle of the sill, where it would do more harm than good), and that the joint between the plaster and the grounds must be covered about $\frac{3}{8}$ in. by the architrave, also that the grounds should not be bevelled more than $\frac{1}{4}$ in., otherwise they cannot be "cramped up" without damage to the edges.

The French casement sections shown in Figs. 3–5, page 68, illustrate the details of construction of this class of window, the frames of which are invariably made "solid" as distinguished from the built-up or "cased" construction of the sash window frame described above.

Fig. 3 is a vertical section (broken) through a large frame, with the casements opening into the room. In such cases it is necessary to fix a "weather board" (*W*) right across the outside of the casements to throw the water well off the sill; the joint at the meeting stiles requires bevelling, as shown in the horizontal section, Fig. 4, so that the casement may open freely; the joint is made tangent to the circle described by the sash in its path. The ends of the weather board are sometimes sunk $\frac{1}{4}$ in. into the jamb and mullion, so that water shall not enter there.

The sill in this frame has a tongue (*A*) worked in the solid, which is cemented into a groove in the stone sill for the purpose of keeping water from passing between them. The transom overhangs the jambs, to throw the water well clear, and a throating sunk beneath intercepts any that may run in under the edge. The fanlight opens inwards and is hung to the transom.

The dotted lines on the casements indicate the tenons which are double, in the meeting stiles, to clear the hook joint shown in Fig. 4. The mullion, on the side towards the central opening, has a $\frac{1}{2}$ in. groove sunk in the rebate, into which a cock-bead on the casement stile fits. This renders

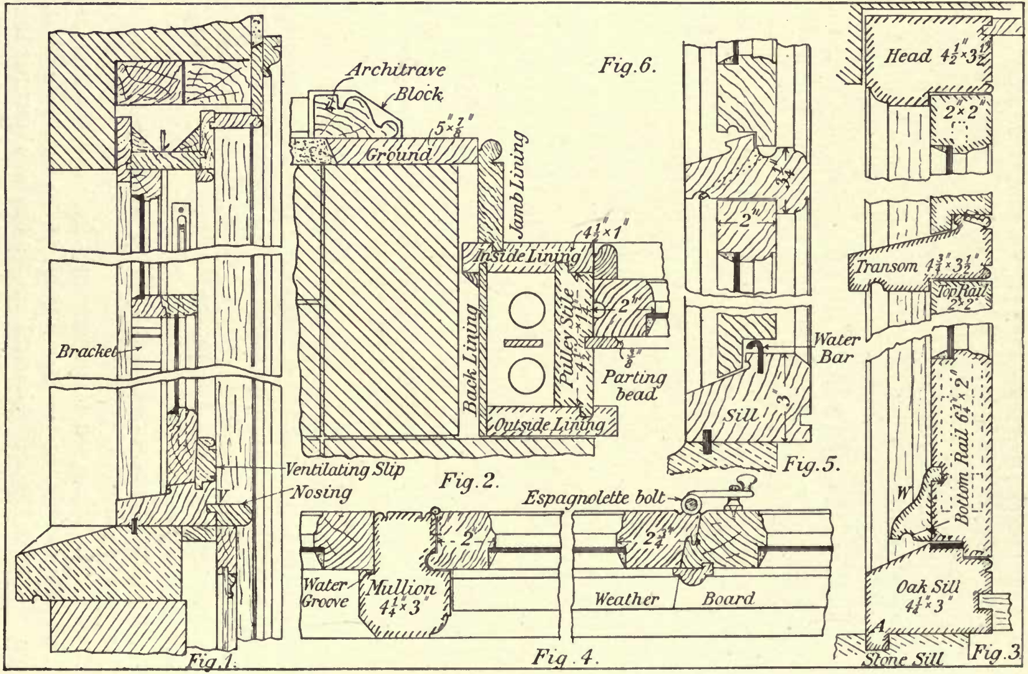


Fig.1.
Bracket
Ventilating Slip
Nosing
Architrave
Block
5"×7/8"
Ground
Jamb Lining
Inside Lining
4 1/2"×1"
Back Lining
Pulley Stile 4 1/2"×1 1/4"
2"
3/8"
Parting bead
Outside Lining
Fig. 2.
Fig.6.
3 1/4"
2"
Water Bar
3"
Sill
Fig.5.
Espagnolette bolt
2"
2 1/4"
Water Groove
Mullion 4 1/4"×3"
Weather Board
Fig. 4.
Head 4 1/2"×3 1/2"
2"×2"
Transom 4 3/4"×3 1/2"
Top Rail 2"×2"
W
Bottom Rail 6 1/4"×2"
Oak Sill 4 1/4"×3"
A
Stone Sill
Fig.3

Windows—Sash and Casement Details

the joint watertight. The side lights are shown as fixed; the small groove is a precaution to check any water that may gain access through the shrinkage of the mullion.

An outward-opening casement is shown in Fig 6. This frame has a metal water bar, in addition to the weathering and throating of the sill, to prevent snow drifting in. As French casements are used also as doorways it is advisable to have metal upon the sills to prevent wear of the parts. The transom in this case is made flush with the jambs, and as the fanlight is hung at the top, the bottom opens inwards, consequently rain is liable to be blown in at the joint; this is caught in a large groove sunk in the rebate and conveyed through a "weep pipe" to the throating outside.

The head of this frame is rebated in the same way that Fig. 3 is, but is moulded to match the transom, and in both cases the jambs would be of the same section as the heads.

**Shop Fittings** (a draper's counter, page 70).—This example will be found much easier to draw than to construct, and a brief description of the parts will be necessary to the understanding of the drawings. These are necessarily grouped for convenience to suit the size of the page, and should be redrawn with more freedom of space. The plan, Fig. 1, shows the general arrangement; the part to the right of the line *A–A* is a section through the drawer compartments, and to the left of the line the parts immediately below the top are shown. It will be seen the counter has a narrow return end without drawers, and with a door and lifting flap between it and the main counter. The general disposition of these parts is more graphically shown in the isometric drawing, page 95. Fig. 2 is a reverse or back elevation of the main counter, showing interior fittings. Fig. 3 is a front elevation of the return end, but, apart from the doorway, applies equally to the main counter. Fig. 4 is an enlarged vertical section—broken to avoid reducing the scale of the parts, all the parts not entirely shown being repeats of what is shown—on *A–A*, showing the method of fitting the drawers to the case, and the fixing of the top by buttons, which

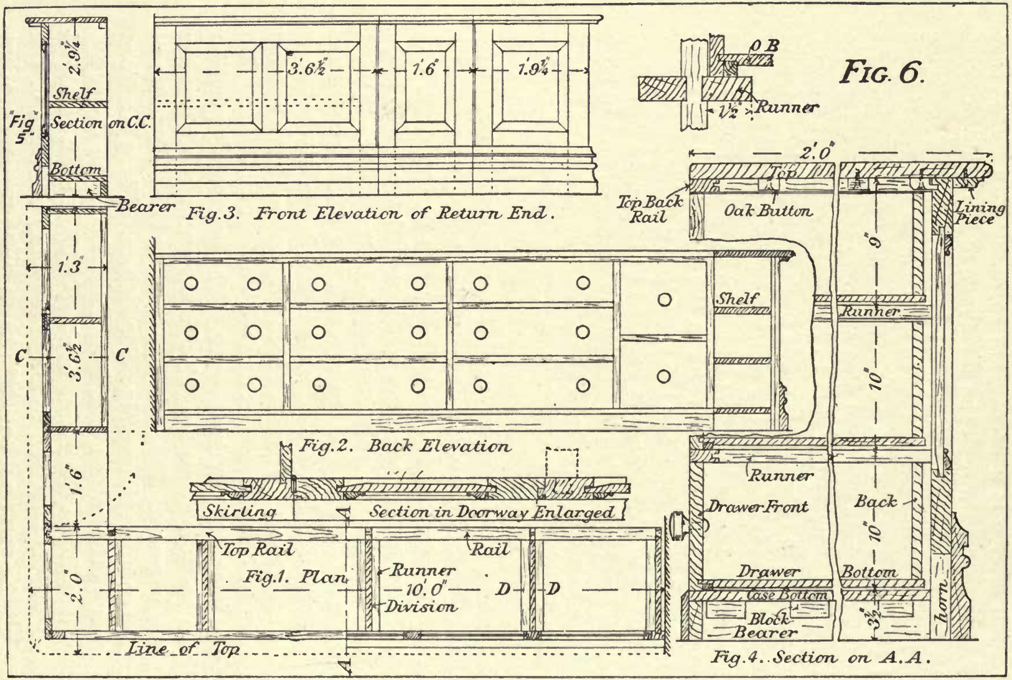


Fig. 6.
O B
Runner
1½"
2' 0"
Top
Oak Button
Top Back Rail
Lining Piece
9"
Runner
10"
Back
10"
Bottom
3½"
horn
Runner
Drawer Front
Drawer
Case Bottom
Block
Bearer
Fig. 4. Section on A.A.
2' 9¼"
Shelf
"Fig 5" Section on C.C.
Bottom
Bearer
3' 6½"
1' 6"
1' 9¼"
Fig. 3. Front Elevation of Return End.
Shelf
Fig. 2. Back Elevation
Skirting
Section in Doorway Enlarged
1' 3"
C
3' 6½"
C
1' 6"
2' 0"
Top Rail
Rail
Fig. 1. Plan
Runner
10' 0"
Division
D
D
Line of Top
A
A

Projections of a Draper's Counter and Underfittings

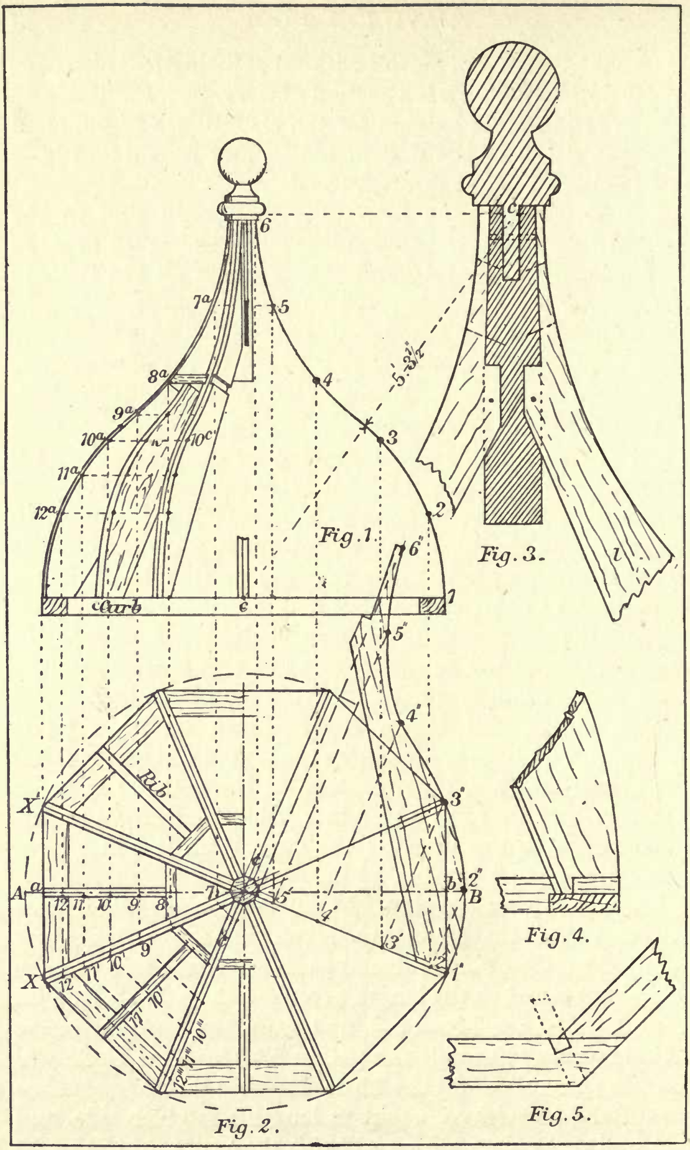
Fig. 1. Sectional Plan. Fig. 2. Back Elevation. Fig. 3. Front Elevation. Fig. 4. Enlarged Section. Fig. 5. Section of Return. Fig. 6. Section of Division and Runners. Fig. 7. Section through Door

allows it to swell and shrink without splitting (see also page 95 for details). Fig. 5 is a section of the return counter, and its use is to obtain heights for the elevation. Fig. 6 is an enlarged detail of the drawer blocks and runners. Fig. 7 is an enlarged detail through the door, etc.

Lay down the plan in outline first, according to the figured dimensions, then reproduce Fig. 4 unbroken to given dimensions. Work this with care, because all the parts in the smaller scale drawing will be taken from it. No particular order need be taken in making such a drawing, other than to observe the general rule to get in the outline first, then the main features, leaving small details until the last, so that in case of any error in the main dimensions less time will have to be lost when making corrections. Also remember that in technical drawing it is the important things that count, not feeble fidelity to truth ; for instance, to make my meaning clear, it is important to draw the handles of the drawers exactly *where* they are wanted, but it is not important to show their detail of moulding, or even their exact size ; in practice, the specification will sufficiently indicate this to the constructor. See also remarks on the same subject in Chapter IX., " Workshop Drawings."

**The Octagonal Ogee Roof** shown on page 72 is suitable for a turret or a pavilion roof. We will assume that the given data are, that the side of the octagon is to be 3 ft. 4 in. and the span 8 ft. 3 in. ; height, 8 ft. from underside of curb to top of ribs ; the curb, 6 in. × 4 in. ; hips, 2 in. ; ribs 1½ in. ; purlins, 1½ in.

Proceed to draw the plan. At any convenient place, draw the line *A–B* and set off on it the given span as at *a–b* ; at these points draw lines perpendicular to *A–B* on each side. Make these lines equal to the length given for the side—3 ft. 4 in. as at *X–X′* ; then bisect *a–b*, and from the centre describe a circle passing through the points *X–X′*. This circle will contain the ends of all the hips. Around its circumference set off eight divisions, equal in length the given side, and join up these points, which will give the outline of the curb ;


6
7a
5
8a
4
9a
10a
10c
3
11a
12a
2
Fig. 1.
6"
1
Curb
c
5'-3½"
5"
4"
3"
2"
B
1'
Fig. 3.
l
Rib
X'
A
a
12
11
10
9
8
7
c
5'
4'
3'
b
2'
9'
10'
11'
12'
X
10"
11"
12"
Fig. 2.
Fig. 4.
Fig. 5.

An Ogee Pavilion Roof

Fig. 1. Sectional Elevation. Fig. 2. Plan. Fig. 3. Joints at Finial. Figs. 4 and 5. Joints at Foot of Ribs

draw in the inside edges parallel. Draw diagonal lines joining the opposite eight angles, and on each side of these draw in half the thickness of the hips. The octagonal finial is 7 in. in diameter. The purlins are drawn parallel with the curb sides, and at such a distance from the finial that the greatest distance between the hips above the purlin will not exceed one foot, otherwise excessively thick boarding will be necessary for covering. The covering boards in this case will run horizontally. At the middle of each bay draw in an intermediate rib, as shown in Fig. 2.

The elevation, Fig. 1, is also shown as a section of the roof on the line *A–B*, which is usually placed parallel with the principal front of the building.

Before completing the section we will consider the method of deducing the shape of the hip or angle rib from the given section, as shown on the right-hand halves of Figs. 1 and 2.

**To obtain Mould for Shape of Hips.**—Draw the approved outline of roof by describing curves of contrary flexure as shown; the given radius is 5 ft. 3½ in. and the centres are upon levels taken at the top of curve and top of ribs—in other words, at the springings. Take any number of points in the curve, as 1, 2, 3, 4, 5, 6, and drop projectors from them into the plan, cutting either of the hips (centre line) in points 1′, 2′, 3′, 4′, 5′, 6′. Upon these points erect perpendiculars to the plan of the hip, and make them equal in height to the same numbered ordinates in Fig. 1, measuring the latter from the top side of curb. Having obtained the points, 1″, 2″, 3″, 4″, 5″, 6″, draw the curve through them. This mould will give the shape to cut the hips out to, also the line of "backing," if moved inward horizontally on the curb, until its edge coincides with the side of the hip as shown in the plan. This will be better understood by referring to the elevation, where the hip just in front of *A* is shown in elevation, with the backing of one side, the other side being, of course, invisible.

**To draw the Elevation.**—Having produced the outline as described previously, divide it into a number of parts as at *7a, 8a, 9a, 10a, 11a, 12a* ; from these points draw horizontal projectors across the elevation—in the example, only one-half is shown—also drop projectors from the same points into the plan cutting the line *A–B*, as shown, in points 7, 8, 9, 10, 11, 12 ; this locates the position of the numbered points in the plan, and as the surface of each bay on a line parallel with its curb is straight across from hip to hip, it will be obvious that if the points 1, 2, etc., are projected to the next hip in planes parallel to the curb they will locate similar points upon that hip. Having done so, reproject them into the elevation to meet the corresponding numbered horizontal projectors, and the intersections will be points in the curve of the hip. Again, we may take the projectors a step farther, to an intermediate rib, and in like manner obtain its projection ; the method of locating the points will be clear by following the numbers, and the curves can be drawn through the points so obtained. Fig. 3 is an enlarged detail of the joints in the finial; Figs. 4 and 5 a side elevation and plan of the joints at foot of hip and angle of curb.

**Lantern Lights.**—Lanterns are lights in a roof ; they differ from the simpler form of skylight in that they have not only top lights but also side lights more or less vertically arranged. A lantern consists of a rectangular or polygonal frame composed of sills, heads and corner posts, with sometimes intermediate mullions ; these openings are fitted with sashes sometimes fixed and sometimes hung, either by hinges to the top or centre pivots at the sides. The roof is sometimes covered with slates or lead, but is usually glazed also, with either movable or fixed lights, fitting into hip and cross rafters. The lantern itself is usually raised from the roof upon a rough curb or frame of timber, covered with lead outside and having panelled framing inside. There are great varieties of detail, several of which are shown in the author's "Modern Practical Joinery." The illustration accompanying this lesson is designed to meet the requirements of the following examination question, and is selected as indicating several difficulties in construction :—

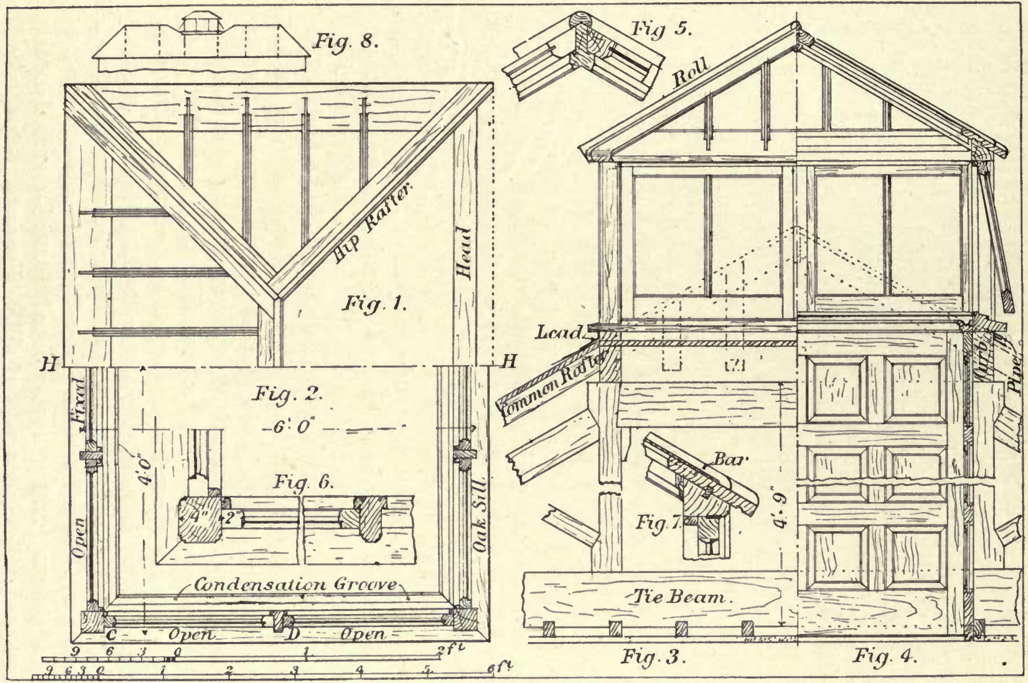


Fig. 8.
Fig 5.
Roll
Hip Rafter.
Head
Fig. 1.
H
H
Lead
Common Rafter
Fig. 2.
6' 0"
4' 0"
Fixed
Fig. 6.
4"
2"
Open
Oak Sill
Condensation Groove
C
Open
D
Open
9 6 3 0 1 2ft
9 6 3 0 1 2 3 4 5 6ft
Bar
Fig. 7.
4' 9"
Curb
Pipe
Tie Beam.
Fig. 3.
Fig. 4.

A Lantern Light in a Hipped Roof

Fig. 1. Half Plan of Skylights. Fig. 2. Half Plan of Side Lights. Fig. 3. Half End Elevation. Fig. 4. Half Vertical Section. Fig. 5. Detail at Ridge. Fig. 6. Details of Angle Post. Fig. 7. Detail of Lantern Head. Fig. 8. Key Sketch of Lantern and Roof

" Draw the plan, elevation and section of a lantern light, measuring 6 ft. × 8 ft., to be at the ridge of the roof of a billiard-room. To have upright sides glazed and partly to open, the roof glazed but not to open. The lantern to be ornamental."

It is unusual to have a ridge roof to a billiard-room, these rooms being generally on ground or first floors having flat roofs. Light is required all round, which complicates the treatment.

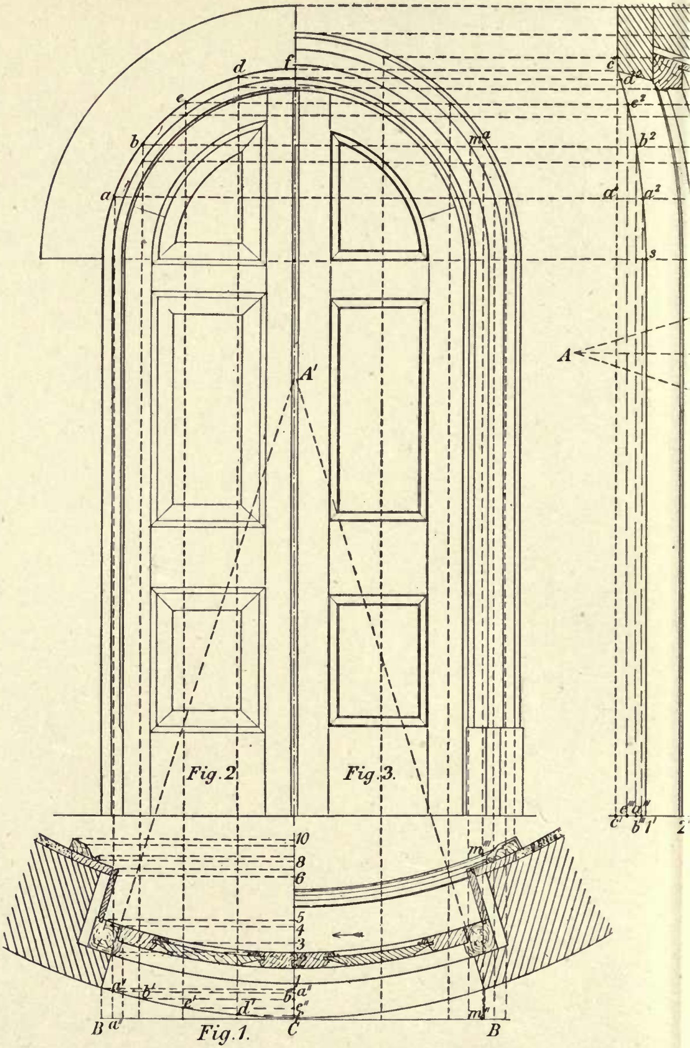
The sketch diagram, Fig. 8, indicates how the roof is hipped back for the purpose of obtaining sufficient room to open the end lights. Lights hung at the top are the best for billiard-rooms, as centre-hung lights may allow rain to be blown in on the table. Fig. 1 is a half-plan of the skylights, the right-hand light being omitted to show the hip rafter, which is similar in detail to the ridge section, Fig. 5, a lamb's-tongue moulding being worked upon its under edge. The bars are checked into the bottom rails, as shown by the dotted lines in Fig. 7. Fig. 2 is a half-horizontal section through the lantern itself, and details of the corner posts and mullions are given enlarged in Fig. 6. Figs. 3 and 4 are half-end elevation and cross section respectively, the lower part of the former being in section to show the queen post truss necessary to carry the lantern. The interior of the opening in the roof is lined with a 1½ in. ogee moulded and panelled framing. Above this is a thick moulding, with a gutter formed in its upper side to receive any condensed water or to catch any rain that might drift in ; this escapes through copper pipes at each end of the sills, as shown in Fig. 4. The lights are opened by means of rackwork not shown in the drawing. The oak sills are mitred and bolted together at the corners, and the posts are stub tenoned to them, and secured with coach screws. Sheet lead is dressed up the face of the curb and an apron piece is turned over and enters a groove in the under side of sill. The curb is dovetailed and spiked at the angles. The roof lights may be fixed with an inserted tongue, as in Fig. 7, or a solid tongue formed on the head, as at *B,* Fig. 4. The stiles of the top lights are grooved for the glass, not rebated. The dotted lines in Fig. 8 indicate position of trusses, the outer four being king post trusses.

**Circle-on-Circle Entrance Doors and Frame.**—This is an example of projection that will require careful and painstaking work on the part of the student if he is to succeed. The author is not aware that this particular form of circle-on-circle work has hitherto been dealt with in books, though doubtless now it will become common enough. It is perhaps also the reason that architects rarely design door frames in this manner, as it is difficult to get the work properly done. This is not the place to enter into the practical details of construction, the remarks here being confined to the methods of producing the drawings and obtaining the moulds. There is a full description in "Modern Practical Joinery" of how these frames are to be constructed when based upon the solid known as the cuneoid, and generally those instructions would apply equally to the frame, etc., now to be described. The head of this frame, also of the soffit lining and the architrave, is based upon the cone, as indicated in the small sketch, Fig. 7—that is, the edge of the frame and face of the lining radiate equally at the crown and springings.

The plan should be first drawn ; and should not present much difficulty at this stage ; a centre line should be drawn and produced into the elevation, and the centre of the plan curves located upon it, by producing the splayed reveals until they intersect at *A'*. This forms the apex of a cone (or, to be exact, a semi-cone), in which the surface of the parts composing the head lie, and becomes the common centre for describing the various curves in the plan. Having finished the plan so far as the members of the frame, etc., are concerned, the elevation may be projected therefrom.

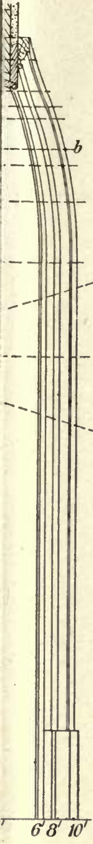
The opening in the wall should first be drawn, and it should be noted that, although the head is shown as a semicircle on the flat, it is not so actually, the true contour being elliptic. What is actually drawn in the elevation is a projection upon a plane standing on the line *B–B*. The dotted projectors indicate where the various lines in the elevation are obtained from in the plan, and no difficulty should be experienced in tracing these; and we can now proceed with the sectional elevation, Fig. 3, which is the really difficult part of this example.

**To obtain the Vertical Section.**—Draw the ground line, mark point *C′*, and project it to the head. This point represents the highest point of the reveal in the brickwork, as indicated by the dotted projector *c′–c″*; intersect this by a horizontal projector from the crown of the arch *f* as shown. Next consider that the section we are drawing is a view obtained by looking in the direction of the arrow on Fig. 1, at a plane passing through the line *C–A′*; if then we draw projectors perpendicular to *C–A′* from the various members and transfer these to the ground line in Fig. 4, as points 1′, 2′, 3′, 4′, 5′, etc., the location of the various edges will be obtained for projecting into elevation up to the springing line, where the curves commence; and we next have to plot points in these. Let us take the sight line of the opening as a starting point. Divide the elevation of this line into as many parts as convenient, as at *a, b, e, d, f*. Draw horizontal projectors from these points across the section, also drop projectors from them into the plan, cutting the line of the arch therein in points *a′, b′, e′, d′, f′*, project the intersection points to *C–A′* as shown by the chain lines; then transfer them to the ground line in Fig. 3, as at *a‴, b‴, e‴*, etc., and raise perpendiculars to intersect the horizontals from the original points *a, b, e*, etc. These intersections give the points $a^2$, $b^2$, $e^2$, $d^2$, through which to draw the curved edge of the arch soffit in sectional elevation. They will be easily followed by inspecting the drawing. The arrises of the frame, the lining and the architrave are obtained in like manner, by producing the projectors in the plan, to cut the desired line, then projecting these points to the line of section and transferring them to Fig. 4, where they are to be inter-


d
f
e
b
m
a
c
d²
e²
b²
a¹
a²
s
A
A′
Fig.2
Fig.3.
10
8
6
5
4
3
a′
b′
c′
d′
b
a″
c″
m‴
m″
e″
d″
c′
b″
1′
2
B
a′
Fig.1.
C
B

Circle-on-Circle Entra

Fig. 1. Plans. Fig. 2. Outside Elevation. Fig. 3. Inside Elevation.
Fig. 6. Method of obtaining Face Mould. Fig. 7. Constructional Diagr



.4.

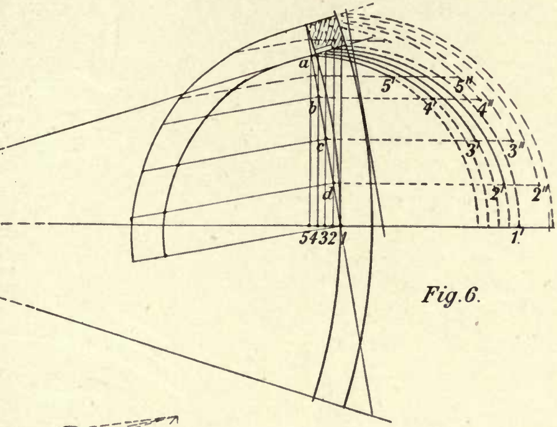

a
b
c
d
5'
5''
4'
4''
3'
3''
2'
2''
5432 1
1'

Fig. 6.

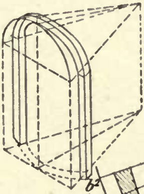


Fig. 7.

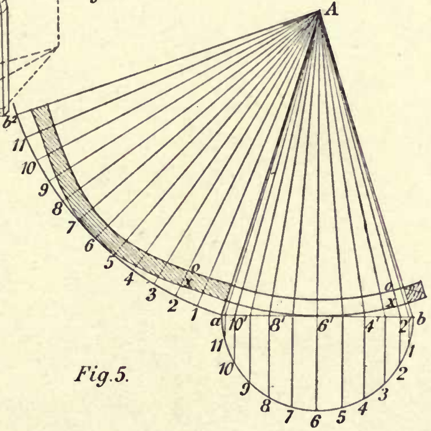

A
b²
11
10
9
8
7
6
5
4
3
2
1
o
x
o
x
a
10'
8'
6'
4'
2'
b
11
10
9
8
7
6
5
4
3
2
1

Fig. 5.

Doors and Frame

4. Vertical Section. Fig. 5. Method of obtaining Soffit Mould.

*To come between pp.* 78-79.

sected by horizontal projectors drawn from the corresponding points in the elevation ; nearly all of these are shown, and, if dealt with one point at a time, following each through its several positions, the necessary data for drawing the curves will be obtained without great difficulty.

It will be seen that, to avoid a confusing mass of lines, the same projector has been used upon several arrises, but it must be noted that it is necessary to project into the plan the new points where the horizontal projector intersects the arris in question, and, to simplify the procedure, it is best to deal with one arris at a time and not to copy off all the projectors shown on the plate straight away, as this is given in its completed state, with all the construction lines upon it. In the usual way many of these lines would have been removed after serving their purpose, leaving the drawing clear for subsequent projectors.

**To obtain the Soffit Mould**, Fig. 5.—This figure is drawn to half the scale of Fig. 1, for the purpose of placing it on the same page, but in the reproduction must be drawn to the same scale as the rest of the drawing. The drawing shows the mould for the soffit of the frame, but the method will be the same for obtaining that of the lining and the architrave, also edge of the ground.

*A–a–b* is the plan of the cone formed by the radiating jambs ; the semicircle is the elevation of its end laid down or rebated into the horizontal plane. Divide the semicircle into a number of equal parts as shown, project these points to *a–b*, then carry them to the apex *A*, as shown ; next describe the development of the edge of the semi-cone. With *A* as centre and *A–a* as radius, describe the arc *a*–12. Make this equal in length to the semicircle a–6–*b* by stepping around same with the compasses and transferring a like number of steps to the development, the greater the number the greater the accuracy of the length obtained. Then transfer in a similar manner the numbered points 1 to 11. Draw lines from them to the apex *A*. The triangle then obtained will be the shape of the covering or " envelope " of the semi-cone. Next describe the plan of the frame (it may be pointed out here that this all might be done upon the original plan ; a separate drawing is used only to avoid confusion of lines), and set off upon the development along the radiating lines points at a like distance from the edge of the envelope that the edges of the frame are, in plan from the line *a–b* as measured on the correspondingly numbered radial line, and so obtain a series of points through which to draw the mould. For example, points *2–x–o* on the development are made equal to points *2–x–o* in the plan.

**To obtain the Face Mould of Frame**, Fig. 6.—Again draw the plan of frame and the containing cone. Assuming the head to be made in two pieces, which it may easily be, draw the line 1–*a*, joining the extremities of the curve; parallel with this draw a second line tangent to the curve. This shows thickness of stuff required to get the head out of. Next divide the line 1–*a* into a number of parts, as *a*, *b*, *c*, *d*, *e*. Through these points draw perpendiculars to the centre line *A*–1, cutting the side of the cone ; with the points 1, 2, 3, 4, 5 upon the centre line as centres, and the distance of each point from the side of the cone as radii, describe arcs as shown in dotted lines. Intersect these by projectors from the points *b*, *c*, *d*, 1, drawn parallel with the centre line *A–C*, thus obtaining points 1′, 2′, 3′, 4′, 5′. Next erect perpendiculars to 1–*a* from points 1, *d*, *c*, *b*, *a*, and make them equal in length to the similarly numbered dotted ordinates in the plan, and draw the curve through the points so found. In practice the back edge would be gauged parallel from the front, but geometrically it may be obtained in like manner to the soffit edge by producing the projectors as shown at 2′, 3″, 4″ 5″.

The principle upon which the above construction is based is that any section of a cone passing through both sides, as shown by the line *a*–1 produced, forms an ellipse ; also any section of a cone parallel with its end or perpendicular to its axis is a circle (in the case of a semi-cone, a semicircle). If then we find the size of the cone at various points where a perpendicular plane upon the line 1–*a* would pass through it, the points in the circumference of the cone, as indicated by the projectors 1′, 2′, 3′, etc., will also be points in the required ellipse. Only one mould is shown; another is required for the outer face, but the procedure is exactly the same, the superimposing of it on the drawing would only confuse the reader.

The face moulds are used for marking the elevation curves, and after the soffit edge is planed to the lines the soffit mould is applied and by its aid the plan curves are drawn.

## CHAPTER VI

## ISOMETRIC PROJECTION

Derivation of Term Isometric. Theory of Isometric Projection—advantages of the method. To construct a Farish's Scale. A Simple Isometric Scale. Equal Angle Projection—its principles. Mechanical Method of Construction. The Isometric Planes. Examples—a Nest of Shelves. Mortise and Tenon Joint. Non-rectangular Figures. Projecting an Octagonal Prism. An Octagonal Pyramid. A Splayed Washing Tray. A Gallows Bracket. A Dwarf Cupboard. A Brick Quoin and Footings—how bricks should be laid. A Builder's Gantry—method of construction, how to project. A Draper's Counter—details of construction, method of making the projection. Circles and Curves—how they may be rendered in isometric. Projecting a Cylinder. Isometric View of a Moulding

ISOMETRIC projection, or "projection showing equal measurements," as it was described by the inventor, Professor Farish, of Cambridge University, derives its name from two Greek words ; *isos*, equal, and *metron*, a measure, referring to the fundamental principle of the method : that the axial or root lines of the drawing, although reduced, are equal in length or measure, and, therefore, proportionate to the object. One of the chief advantages of this method of drawing is that direct measurements may be taken from the isometric axes or root lines of the drawing just as in orthographic drawings. A further advantage is that three views of the object are combined in one drawing, thus giving it an appearance of solidity that is very convincing ; we are, however, practically limited to one position only, as will be better understood by inspection of the examples than by a written description.

The basis of isometric projection is the relative positions

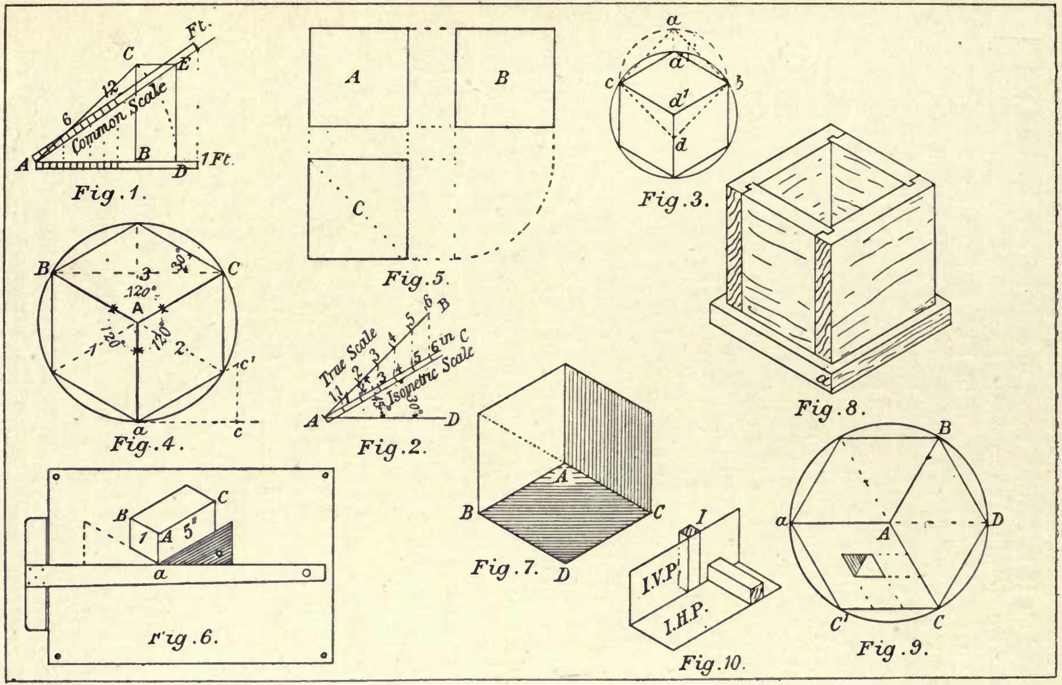


Fig. 1.
A
B
C
D
E
6
12
Common Scale
Ft.
1 Ft.
Fig. 5.
A
B
C
Fig. 3.
a
a′
b
c
d′
d
Fig. 4.
B
C
A
3
30°
120°
120°
120°
1
2
a
c′
c
Fig. 2.
A
B
C
D
True Scale
Isometric Scale
1
2
3
4
5
6
6 in
30°
Fig. 8.
a
Fig. 7.
A
B
C
D
Fig. 6.
A
B
C
a
1
5″
Fig. 10.
I
I.V.P.
I.H.P.
Fig. 9.
a
A
B
C
C′
D

Isometric Projection

Figs. 1 and 2. Isometric Scales. Fig. 3. Diagram illustrating Theory. Fig. 4. The Isometric Axes. Fig. 5. Orthographic Projections of the Cube. Fig. 6. Isometric Projection by Means of Set Square. Fig. 7. Inverse Isometric Projection. Fig. 8. A Box. Fig. 9. A Cube resting on one Edge. Fig. 10. The Isometric Planes which the contiguous sides of a cube assume to the vertical plane, when it is resting upon one of its corners and the diagonal line joining the corners is horizontal. This position is shown by the cube drawn in Fig. 3, page 83, and the lozenge representing the upper surface of the cube differs considerably from the square, which is its actual or orthographic projection, as shown in juxtaposition in dotted lines. This figure will explain why a true isometric drawing is smaller than the object it represents, apart from any scale it may be drawn at. If the square *c–a–b–d*, shown in dotted lines, were revolved on the diagonal *c–b*, until the corner *a* reached point *a′*, the full-line lozenge *c–a′–b–d′* would be its appearance to an observer immediately in front; it would also be, as we shall see presently, the true isometric projection of the square, which is also one side of a cube. It will be obvious that although the position of the sides of the square are altered during its movement, their actual lengths are not; nevertheless it will be found on measuring the projection that the full lines are shorter than the dotted lines, which are the real dimensions, whilst the diagonal *c–b* remains the same throughout. The proportion of an isometric line to the real line it represents is as the square root of 2 is to the square root of 3.

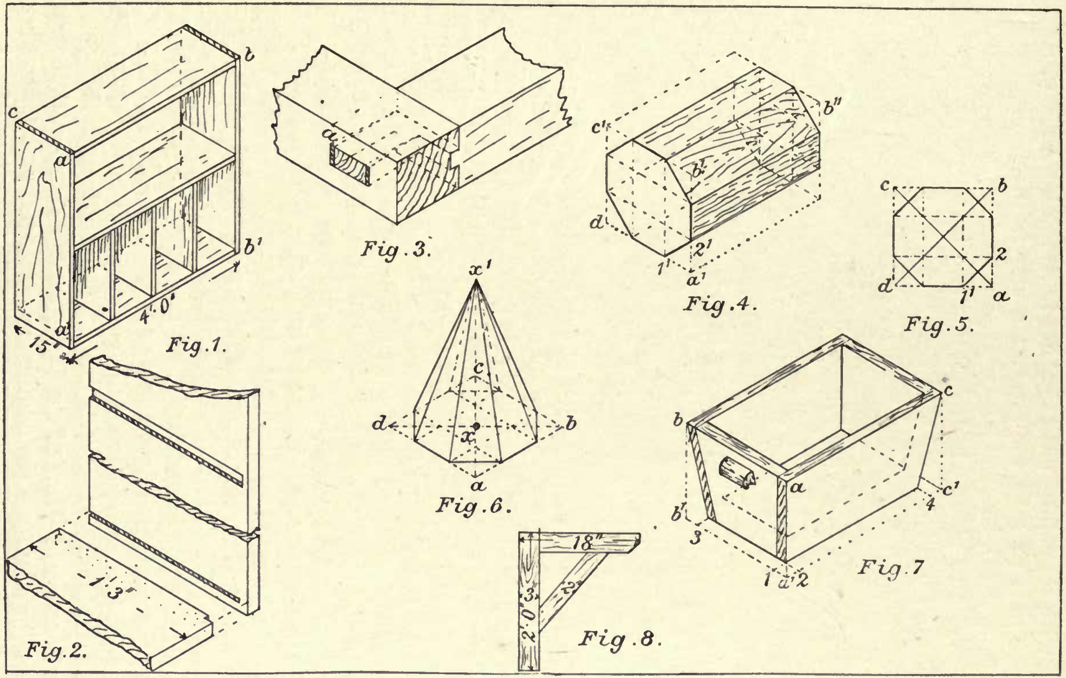
An isometric scale constructed upon the above principle for the purpose of making an isometric projection in due proportion to a given scale is shown in Fig. 1.

**To construct an Isometric Scale.**—Draw two lines, *A–B* and *B–C*, perpendicular to each other and equal in length. Join *A–C*, then *A–B* : *A–C* as $1 : \sqrt[2]{2}$. Next make *A–D* equal in length to *A–C*, and *D–E* parallel to and equal in height to *B–C*. Join *A–E*. Then *A–E* is to *A–D* as the $\sqrt[2]{3}$ is to $\sqrt[2]{2}$. We have now two lines in the desired proportion or ratio to each other, and if we construct a common or regular scale upon the longer line, *A–E*, as shown, and project its divisions perpendicularly to the base line *A–D*, the said divisions will be proportionately reduced thereon, and an isometric scale constructed, with which we can read off dimensions in the same manner that dimensions are read upon an ordinary scale in orthographic drawings. The above is Farish's method, but the same results may be obtained in a simpler manner, as shown in Fig. 2. Here two lines are drawn upon the base line *A–D*, having angles of 45° and 30° respectively between them. The true scale is plotted upon the 45° angle line *A–B*, and the divisions projected as before upon the 30° line *A–C*, which becomes the reduced or isometric scale. This method is based on the construction shown in Fig. 3. Where the dotted line *C–a* is at an angle of 45° with the horizontal diagonal *C–b*, and the full line *c–a′* is at an angle of 30° with the horizontal, and, as previously explained, the full line is the isometric equivalent for the real edge *c–a*, it follows that any portion of the real line would be in like manner represented isometrically by dropping a perpendicular from it to the isometric edge, as shown at *f*.

It is advisable to be acquainted with the above theory of isometric projection for a full understanding of the subject, but in practice it is usual to disregard the fact that an isometric projection is smaller than the object represented, whatever scale may be used, and to mark off the required dimensions with a rule or an ordinary scale upon the three root lines which represent respectively the length, breadth and thickness of the object. This may be safely done, as every part of the drawing is proportionately reduced. The method now to be described has been variously termed pseudo-isometric, conventional isometric and angular projection. Neither term is entirely distinctive or very illuminating, and the writer suggests the term equal angle projection as being more descriptive of the procedure.

It has already been explained upon page 16 that any circle may be divided into 360 equal parts for the purpose of measuring angles, by observing how many degrees or divisions such angle contains, and, if a circle is divided into three equal parts by lines radiating from its centre, it will be obvious that each of these lines will contain 120 degrees, $\frac{360}{3}=120$. This construction is made the basis of the form of isometric projection now to be described. A vertical line is drawn from the centre of Fig. 4 to the circumference *a*. Divide the circumference into three equal parts from point *a*, as at *B* and *C*, join these points to *A*, and we have the three "root lines," or isometric axes, upon which the three cardinal dimensions can be measured direct. These lines are the isometric projections of the edges in the object that are perpendicular to each other, and all other edges or surfaces that are parallel to these edges in the object must be made parallel to these axes in the projection. If this requirement is observed, no mistakes are likely to be made in the projection, and the completion of the cube within the circumscribing circle will be easy.

Observe that upon the tangent line, *a–c* is marked off (to scale) 1 in. long, and that its projector is *a–c′*; the isometric projection lies in this line also, but is shorter, falling in the circumference of the circle, but it measures by the same scale 1 in., which proves that although isometric projection shortens the edges lying in the isometric planes, it does not falsify the dimensions. We may further simplify this method of projection by using the T-square and set square, as shown in Fig. 6, to produce the isometric axes, for if a horizontal line is drawn through point *A* in Fig. 4—that is, perpendicular to *a–A*—the angle contained between such horizontal line and either *A–B* or *A–C* will be 30°; therefore, if we use the set square of 30°, as shown in Fig. 6, we can draw *A–B* and *A–C* with its hypotenuse edge and *A–a* with its right-angled edge, and subsequently any parallel line or edge by moving the set square along the T-square to the required point. No difficulty should be experienced in drawing the remaining figures upon this plate if it be remembered that all dimensions are to be marked along the three root lines and projected parallel therefrom. Fig. 9 represents a cube resting upon one edge, and is produced by revolving the circle shown in


c
b
a
b'
a'
15"
4'.0"
Fig. 1.
-1'3"-
Fig. 2.
a
Fig. 3.
c'
b''
b'
d'
1'
2'
a'
Fig. 4.
c
b
2
d
1'
a
Fig. 5.
x'
c
d
x
b
a
Fig. 6.
b
c
a
b'
c'
4
3
1 a' 2
Fig. 7
18"
2'
3'
2'.0"
Fig. 8.

Isometric Projection

Fig. 1. A Nest of Shelves. Fig. 2. Details of same. Fig. 3. Corner of a Frame. Fig. 4. Projection of an Octagonal Prism. Fig. 5. Preliminary Construction. Fig. 6. An Octagonal Pyramid. Fig. 7. A Canted Tray. Fig. 8. A Bracket example for practice

No. 4, with its points, until *C–c′* lies horizontal. A mortise is shown in it to take the student a step farther. Fig. 10 represents the theoretical isometric planes with prisms lying in them. Any plane which contains two isometric axes is called an isometric plane. Figs. 1, 2, 3, page 87, are rectangular figures that will not offer much difficulty to the student.

**The Nest of Shelves**, Fig. 1, should be commenced by drawing the root lines, *a–a′*, *a–b*, *a–c*, to the given dimensions —preferably not less than three times the scale of the copy. When these are drawn, complete the outline of the case by drawing parallels, then mark off the thickness of the sides equal to 1 in., and space out the shelf and divisions. Fig. 2 is an enlarged detail of one side and end of the bottom, showing how the case is jointed and the shelf housed in.

**A Corner of a Frame with Mortise and Tenon Joint** is shown in Fig. 3. Probably no difficulty will be met with in drawing this until the mortise is reached. The position of this must be located upon the root line by projecting across the inside of the rail to *a*, and dropping a perpendicular. Mark off a parallel line to the width of the tenon (as shown, it is half the width of rail), then add the wedging; finally draw in the sides of the mortise and project them to the salient angle to project into the adjacent plane, and so obtain the haunching. Finish by indicating the tenon, etc., by dotted lines drawn from the visible faces.

**To draw Non-Rectangular Figures** by this method it is first requisite to enclose them within a rectangular figure and, placing this isometrically, we can mark off the points where the contained figure cuts or touches the sides of the rectangle, just as we should dimension points, and, joining up these, obtain an isometric projection of the figure. Fig. 4 is an **Isometric View of an Octagonal Prism**, and the dotted lines indicate the containing rectangle, produced as shown in Fig. 5. It will be observed that the face of the prism lying below the line *b′–b″* is shown much wider than

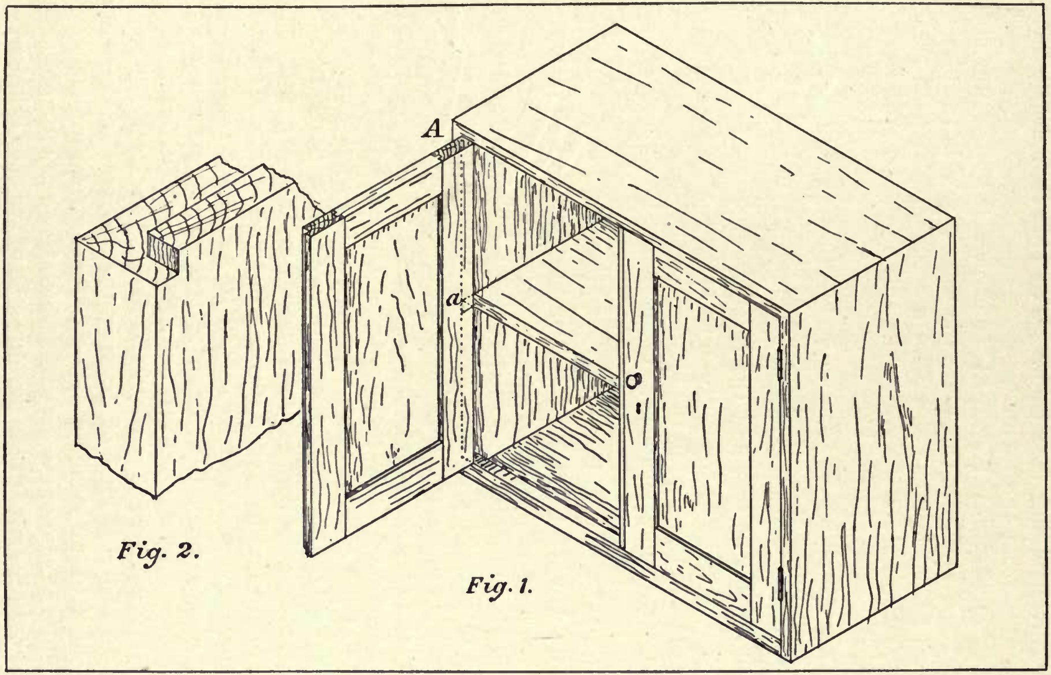


Fig. 2.

Fig. 1.

Isometric Projection

Fig. 1. A Dwarf Cupboard. Fig. 2. Enlarged Detail of Joint at *A*

the corresponding face below *c–c'*. This is a defect inseparable from the method.

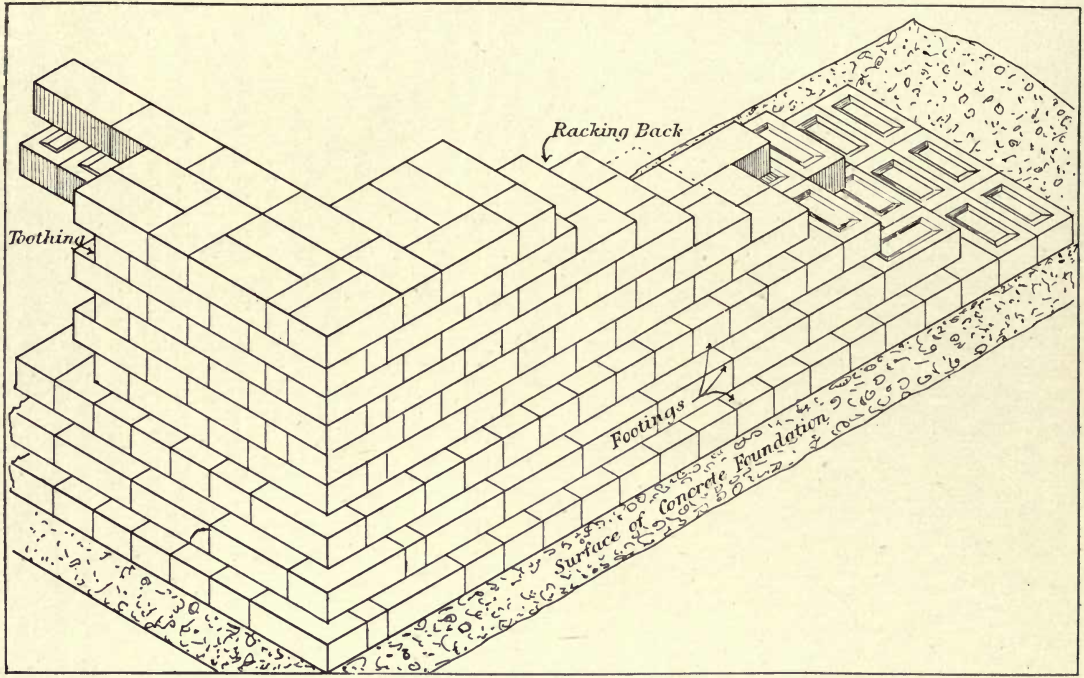
**An Octagonal Pyramid** is shown isometrically in Fig. 6. To produce this place the base, Fig. 5, in the horizontal isometric plane and erect a perpendicular from the centre *X*. Locate the apex upon this and draw lines to it from the angles in the base.

**The Washing Tray**, Fig. 7, has four equally sloping sides, therefore is non-rectangular at either side. To draw it the dotted rectangular prism must be made upon it to the required size of top, and the height. Then mark off the amount of slope at the bottom, as at *a'*–1, *a'*–2, *b'*–3, etc., and draw in the sides to the intersections.

**The Gallows Bracket**, Fig. 8, shown in orthographic projection is given as an exercise. The student should put it into isometric projection.

**The Dwarf Cupboard** shown in plan and elevation on page 51 is drawn isometrically on page 89. This is distinctly an example that can be better rendered in isometric than in orthographic projection, so far as giving a clear impression of the construction is concerned.

It is an easy example to draw. Commence as before with the three root lines, making these represent the salient angle of the case, the bottom edges of the front and end respectively. Complete the case by drawing parallels to these, taking the necessary dimensions from page 51. The doors may next be drawn, commencing with the closed one; no instructions should be needed to locate the face lines of the rails and stiles, these, of course, being measured directly upon the root lines, but a little consideration must be given as to what parts of the recessed surfaces will be visible. In this kind of drawing the observer is always supposed to be standing opposite the near salient angle, therefore he cannot see the edges which face *away* from him. Obviously the edge of the hanging stile of the door is in this position, and is not shown, whilst that of the meeting stile is; also that of the bottom rail. The left-hand door is


Toothing
Racking Back
Footings
Surface of Concrete Foundation

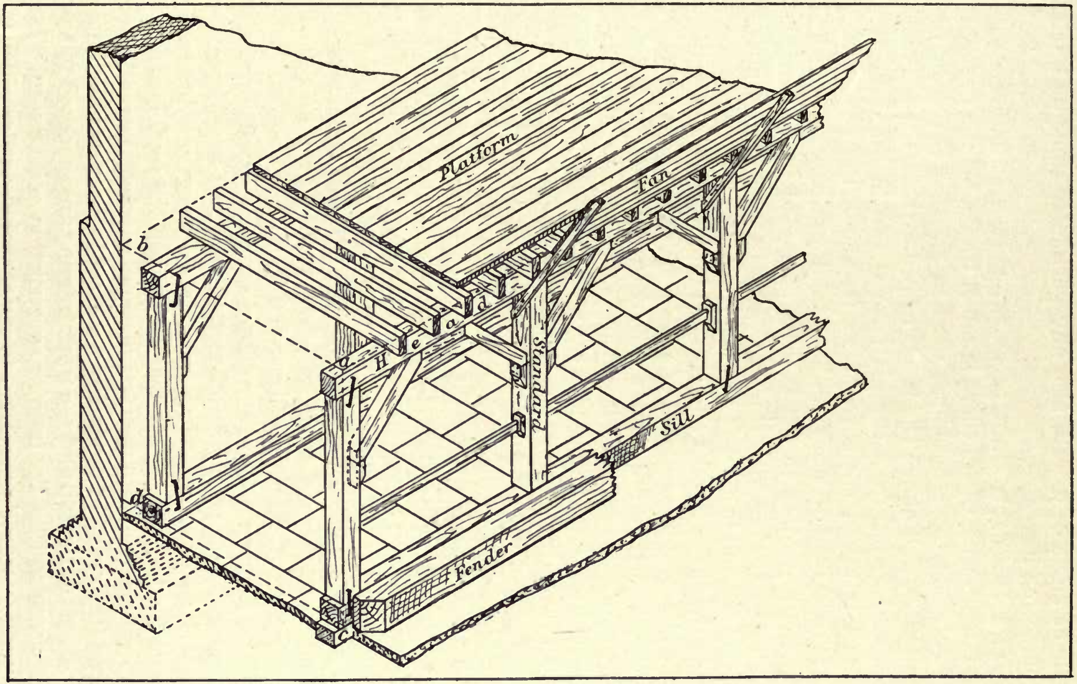
Isometric Projection--A Quoin in Brickwork projected open, and as at this stage the clear opening will be shown, commence the door by projecting the top and bottom edges from the inner angle of the opening. Eventually the lower line will disappear, being hidden by the back face, but it is necessary to first draw it to obtain the size of the door and the thickness.

Set off along the top line, the width as shown in the opening, and draw in the rebate, projecting the back edge ½ in. beyond the rebate line just obtained. Go back to point *A* and set off the thickness, when the inner face may be completed. The filling in of the minor details should offer no difficulty. The position of the shelf is located upon the dotted line representing the inner edge of the case as at *a*, projecting back the thickness of the door to find the plane of the edge of the shelf.

An enlarged detail of the joint between the end and top of the case is shown in Fig. 2. The bottom rail is stub tenoned into the ends and the shelf is housed in $\frac{3}{16}$ in.

**The Quoin of a 14 in. Brick Wall** in single Flemish Bond is shown on page 91, with three courses of footings resting on the surface of the concrete foundations. The drawing further illustrates the technical terms, " toothing," " racking back " and " carrying up the quoin " ; the first being the method of connecting to a cross wall, the second the method of suspending the work in successive set-backs right across the thickness, for the purpose of bonding the continuation of the wall. Some difference of opinion exists among bricklayers as to the best way to lay the bricks, frog up or down, but undoubtedly in all ordinary cases it is better workmanship to lay with the frog upwards, as, placed thus, it is sure to get filled with mortar. The bottom course must in all cases have the frogs uppermost, and the top course the frogs downwards.

Carrying up the quoin is the building up to the two ends of a wall in advance of the remainder for the purpose of lining the courses to keep them level. Quoin is the corner or


Platform
Fan
b
d
a
e
H
a
Standard
Sill
d
Fender
c

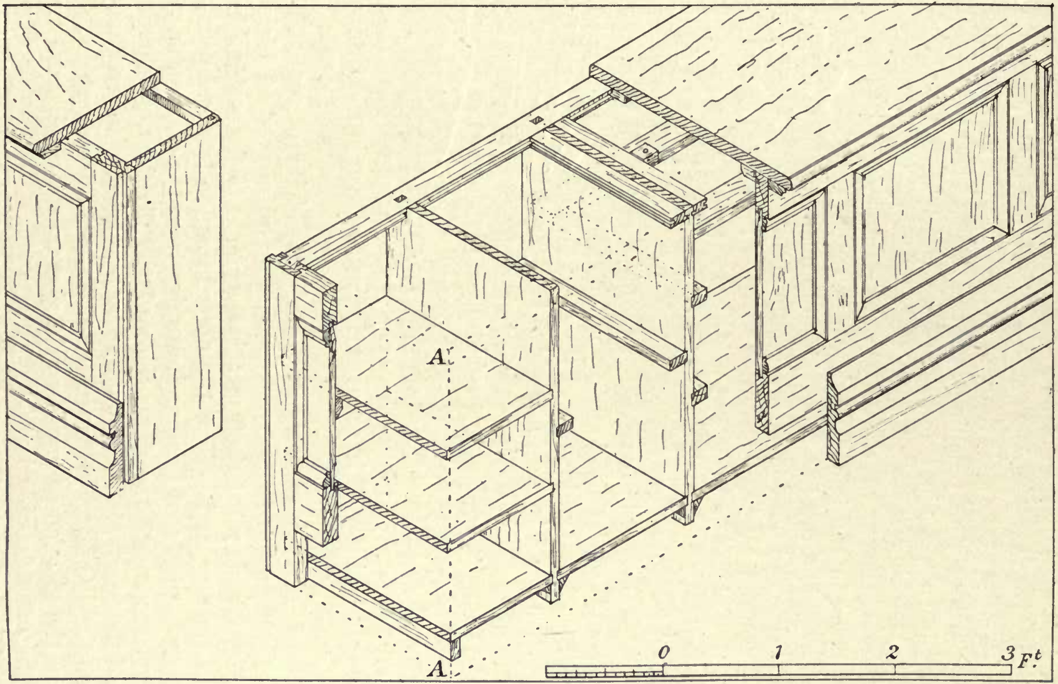
Isometric Projection—A Builder's Gantry

salient angle of a wall, also any particular stone or brick composing it.

**The Builder's Gantry**, page 93, is a structure used in large towns, where there is much traffic, for the purpose of carrying the scaffolding, used in erecting the walls of buildings, well above the heads of pedestrians, the scaffold proper starting from the platform shown in the drawing, which is raised some 10 or 12 ft. above the pavement. It is composed of stout timbers from 7 in. square to 11 in. square, according to the spacing and load to be carried, secured together with timber dogs. In some few instances where the job is expected to last some years, the standards or uprights are framed and tenoned into the heads and sills. The platform is composed of deals such as are used for floor joists, and they are lightly spiked to the heads. A light sloping guard or " fan " is run around the front and ends to prevent material falling into the street.

To draw the gantry, commence by projecting the rectangle, *a–b–c–d*, shown in dotted lines, at an angle of 30°, with the horizontal to the left, and another rectangle level with the floor, towards the right; these two rectangles, placed isometrically, will contain the main structure, and the various dimensions can be scaled off upon the root lines. The chief dimensions are: height, pavement to floor, 11 ft.; width out to out of standards, 9 ft.; distance between standards in front, 9 ft.; space between joists, 1 ft. 3 in.; height of handrail, 3 ft.; height of braces, 6 ft. 6 in.

**The Draper's Counter** shown on page 95, also orthographically on page 70, will test the student's carefulness, and if he does not work accurately to previous instructions as to measuring off the details upon the root lines and projecting them into the picture where required, he need not hope to succeed in producing a correct isometric projection. Portions of the top and the front framing are supposed to be cut away so that the interior construction can be seen. It is perhaps scarcely necessary to say that the counter will not be so made, and the parts shown removed will be continued,

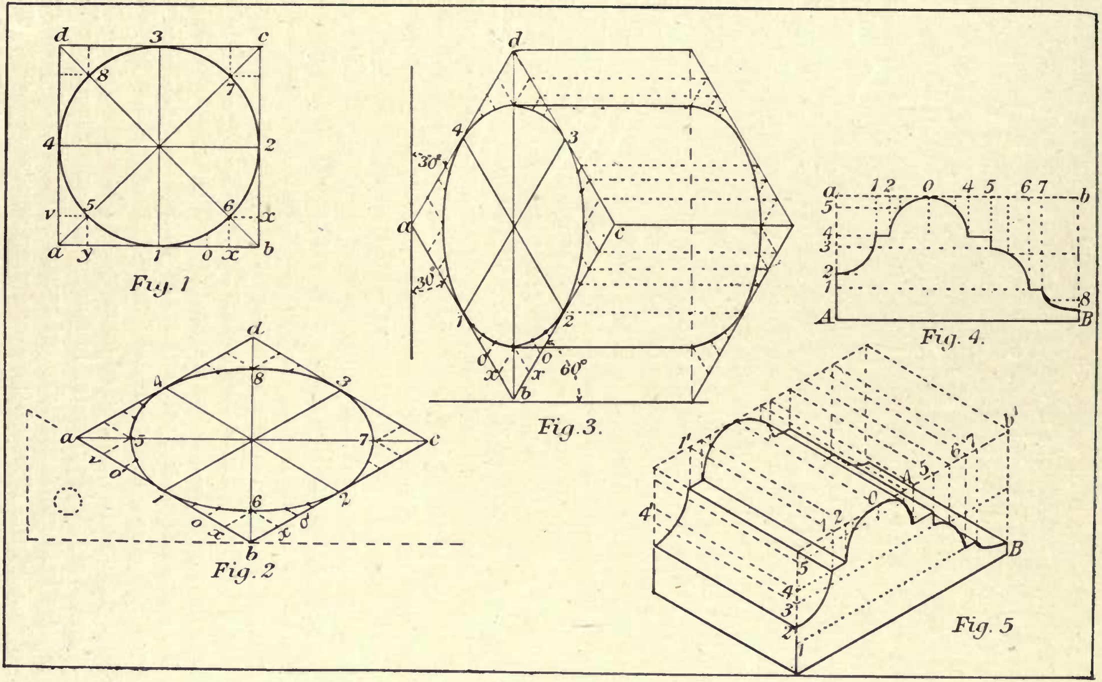


Isometric Projection of a Draper's Counter with Parts removed to show Construction as indicated by the dotted lines. The front of this counter is made of 1½ yellow deal; each section is framed in one piece with stiles at the ends running to the floor, the intermediate mountings stub tenoning into the rails. The bottom rail finishes about 3 in. below the plinth, which is fixed to blocks or "backings" nailed upon the divisions. The plinth or skirting runs across the door in the return end, and is cut at a bevel in the joints, as shown in Fig. 7, page 70, to pass clear. The top has a considerable overhang in front and is thickened outside with a moulded lining screwed on; it is secured by slipping-buttons fitting into grooves in the tilting pieces and screwed underneath; this is to prevent splitting, which such a wide board would be liable to do if fixed immovably.

The carcase is constructed by forming tenons upon the top ends of the divisions in a notch cut to receive the back rail, and at the lower end they are housed or grooved to receive the ⅞ in. bottom, which is secured by gluing angle blocks beneath, the intermediate rails forming divisions for the drawers, double tenoned into the divisions at each end, and the runners are single tenoned into them for ½ in., also housed $\frac{3}{16}$ in. into the uprights. As a rule, dust boards are not provided in these counters; if they were required they would be inserted in grooves similar to those in the tilting pieces.

To draw this example start at *A–A*, which represents the salient angle of the front framing or mitre marked *M* in Fig. 1, page 70. Set off on this the height to the under side of the top, and project the dotted lines to left and right, forming the root lines, and, working from the plan on page 70, space out the dimensions of the divisions, thickness of the front, etc. It would be both wearisome to read and probably useless to give instructions for placing every detail in the picture, as words would give no clearer description than the drawing itself.

**Circles and Curves.**—When a circle is projected isometrically it becomes an ellipse, or, to state the facts with



d
3
c
8
7
4
2
v
5
6
x
a
y
1
o
x
b
d
4
8
3
a
5
7
c
v
o
1
6
2
o
x
x
o
b
d
4
3
30°
a
c
30°
1
2
o
o
x
x
60°
b
a
1 2
0
4 5
6 7
b
5
4
3
2
1
8
A
B
1'
4'
0
1
2
5
4
3
2
1
5
6
7
b'
B

Fig. 1

Fig. 2

Fig. 3.

Fig. 4.

Fig. 5

Isometric Projection of Circles and other Curved Figures more exactness of expression, an ellipse in an isometric projection represents a circle in either plan or elevation, and, from the association of ideas consequent upon the observation of natural phenomena, the mind invariably assumes that a circle is represented when the ellipse is rendered isometrically. Therefore it follows that if we desire to suggest an elliptic solid isometrically the only way in which we can differentiate it from a cylinder is to label it.

The readiest method of rendering the circle isometrically is, as advised for projecting polygons, to enclose it within a square, and to draw projectors from various points in the curve to the sides of the square, then to redraw the square in the form of a rhombus, by projecting its sides at an angle of 30° with the horizontal, thereafter transferring the projected points from the sides of the square to the corresponding sides of the rhombus, and then drawing from these points lines parallel with the root lines, locating the points in the curve upon them from the original drawing and tracing the elliptic curve through these. The method is shown on page 97. Fig. 1 is the circle to be shown isometrically. Proceed to enclose it within the square *a–b–c–d*, whose sides are made to touch the circle. Draw the diagonals *a–c* and *b–d*, also the transverse diameters 1–3 and 2–4. These lines will locate eight points in the curve; if more are required, any number of intermediate points may be plotted by projectors perpendicular to the sides as shown at o, *x*, *y*. Fig. 2 shows the square in isometric projection when it becomes a rhombus. The various perpendiculars are transferred from Fig. 1 to Fig. 2, where they are similarly numbered and their lengths marked—*i.e.* the distance from the adjacent side of the square that the original curve passes through them—and the curve can then be drawn through these points. Fig. 3 shows the method of placing the circle in the vertical plane. If this is projected in the usual manner from the **T**-square held horizontal, the set square of 60° should be used to project the sides of the containing square *a–b–c–d*, and the diagonal *b–d* becomes the major axis of the ellipse. If preferred, the paper may be turned around until *b–d* lies horizontal, when the usual projectors at 30°, as shown at *a*, may be used. As the completion of this end is merely a repeat of Fig. 2 no further instructions should be necessary.

We may convert the plane figure into a solid by producing the angles of the square to the required distance in a horizontal direction, and drawing its repeat to form the distant end. For the purpose of projecting the cylinder, only one half of the square need be drawn, as the view of the distant side will be intercepted by the cylinder.

Having drawn the half-square as shown, carry the various measuring points across the sides of the prism as indicated by the dotted lines, and project them across the end to discover similar points in the curve to those at the front end. The completion of the figure will then be easy. Of course, when the desired cylinder is obtained the various construction lines are removed.

**More Complex Curves** (as Fig. 5, a short length of architrave moulding) can be easily projected by a similar procedure. Enclose the orthographic section, Fig. 4, within a rectangle touching its boundaries, and draw perpendiculars to the sides from the various angles and points in the curves ; number these for ready reference and proceed to place the rectangle into isometric projection, its base and edges forming the root lines as shown in Fig. 5. Then transfer the various points, and number to correspond with the original. Project these across each face with the set square of 30°, and mark off their various lengths, which give all the necessary points for completing the view, that should be clear by an inspection of the figures.

## CHAPTER VII

# OBLIQUE PROJECTION

Limitations, Types, Description of the "Single Scale" Method—its essential defect. "Half Scale" Projection—its dangers, suitability for school demonstrations. The "Official" Method. Theory of Oblique Projection illustrated. Examples—cubes and prisms. A Trussed Partition—details of construction. A New Method—Diminished oblique projection, its advantages. An Oblique Scale—how to construct it. A Ventilating Grating—details of joints. Method of constructing Pentagons. Projection of a pentagonal Prism. Shuttering and Forms in Reinforced Concrete Work. The Carpenter's last resource. Material to use. Size of Forms. How to construct them. Cleats and Props. Method of Drawing

THIS method of drawing is probably the easiest to learn and the simplest to use, for illustrative purposes, of any, and it is to be regretted that, except in the case of objects with a fairly simple outline, it cannot be used for "workshop drawings"—*i.e.* drawings from which the sizes can be transferred directly to the material. The reason of this will presently be obvious. It has already been stated in Chapter I. that there are three varieties of this description of projection in general use, and the author ventures to offer a fourth in the examples on page 107, which, though limited in its scope, gives, he thinks, a somewhat improved effect to the drawings for which it is suitable.

In the first method of oblique projection, the chief face or elevation of the object is drawn, as in orthographic projection, upon a plane parallel to the observer, and the receding surfaces are drawn at any convenient angle, but always in parallel pairs; for this reason the method has been somewhat loosely described as "parallel perspective."

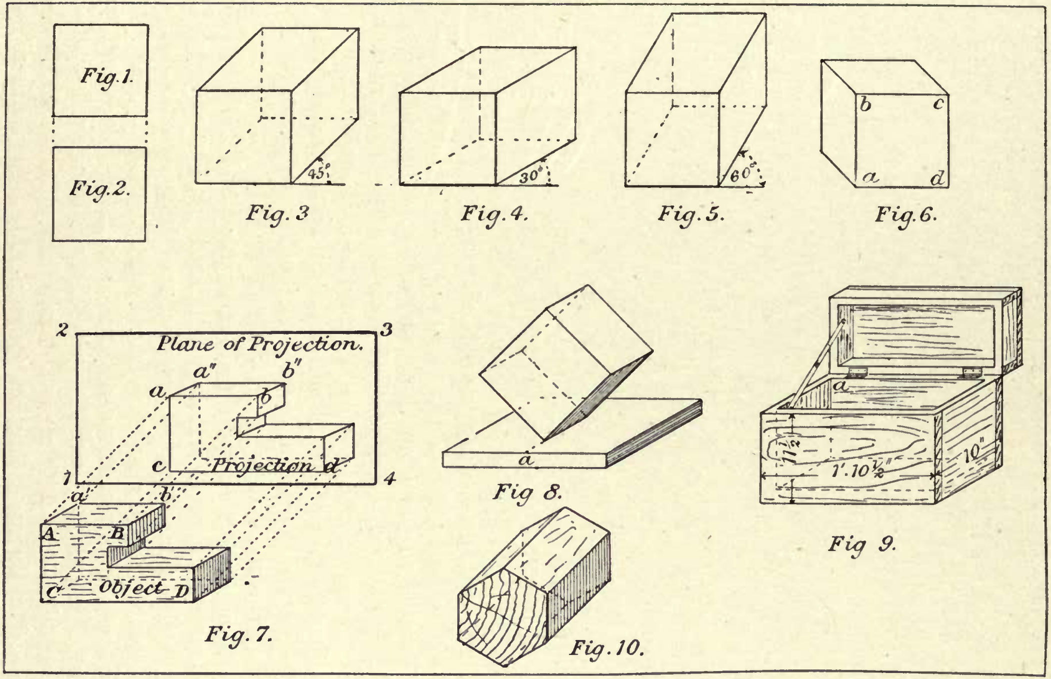


Fig. 1.
Fig. 2.
45°
Fig. 3
30°
Fig. 4.
60°
Fig. 5.
b
c
a
d
Fig. 6.
2
3
Plane of Projection.
a″
b″
a
b
c
Projection
d
1
4
a
b
A
B
C
Object
D
Fig. 7.
a
Fig 8.
a
11½
1′.10½″
10″
Fig 9.
Fig. 10.

Oblique Projection

Figs. 1 and 2. Plan and Elevation of a Cube. Figs. 3 to 5. Cubes projected in Single Scale. Fig. 6. Projection in Double Scale. Fig. 7. Diagram illustrating the Theory of Oblique Projection. Figs. 8 to 10. Examples

The rear face is made parallel to the front one. Figs. 1 and 2, page 101, are the orthographic projections of a cube introduced for the sake of comparison, and Figs. 3, 4 and 5 are oblique projections of the solid at different angles, and the methods of producing them will be so obvious as to need no description. It will be noted that all of the retiring projectors are at angles other than right angles, hence the term " oblique."

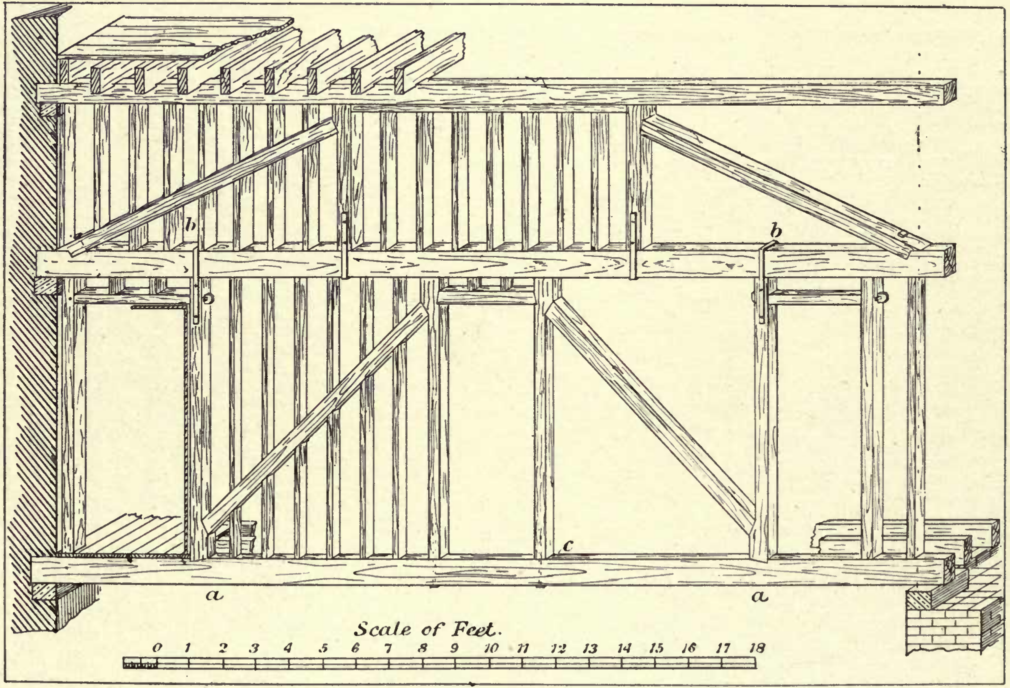
A person to whom this method of projection is unfamiliar will doubtless conclude from the appearance of Figs. 3, 4 and 5 that the oblique side is shown much longer than the front. Of course in a " cube " all the sides are alike, as shown in Figs. 1 and 2, and if these drawings are tested with compasses they will be found so. This false appearance is the essential defect of the method ; and that next to be described is devised to counteract it.

**Half-Scale Oblique Projection.**—In this method, which is shown in Figs. 6 and 8, the front elevation is drawn as before, either full size or to some definite scale, but the measurements made upon the oblique projectors are to half full size or half scale, as the case may be. All lines which are parallel to the front, however, are kept to the same scale throughout. This method undoubtedly gives a more correct impression of the solid than the first method, but the introduction of the second scale renders extreme care on the part of the user necessary, to avoid errors in working to the measurements.

Oblique projection drawing is much used in schools and at classes for manual training, as it lends itself readily to blackboard demonstration purposes, and, in or about 1896, the chief authority on the latter subject, the City and Guilds of London Institute, attempted to place the method upon a scientific basis. They published, in their " programme " of that date, a method and theory that would be accepted at their examinations for manual training teachers' certificates ; the method is shown in Fig. 7, illustrating the **theory of oblique projection**. The object to be drawn (in the example, a small clip or button) is shown pictorially in space. The plane upon which it is to be projected, represented by the rectangle 1–2–3–4, stands vertically behind, and parallel with, the object; projectors are taken from each corner of the face of the object, at an angle of 45° with the horizontal line 1–4, until they meet the plane of projection. These points of impingement are joined by straight lines which are parallel with the edges they represent on the object, thus an exact replica of the face of the object is obtained. Next, at one of the salient angles in the picture, an arbitrary projector is drawn, such as *a–a″* or *b–b.″* This projector determines the angle of the visible sides, therefore all parallel edges are projected parallel with it, and the depth or thickness of the projection is determined by drawing projectors to intersect these, at an angle of 45° from the points on the rear face of the object, as *a′–b′*, etc.

This method could be adapted to give a projection with the object lying at any angle to the plane of projection, but no good purpose would seem to be served by it except as a mental exercise, because the object must first be drawn pictorially, when the projection seems superfluous. Fig. 8 on this plate is an example drawn in the half-scale method of a cube placed in the middle of a slab, and resting upon one edge, with its adjacent sides at an angle of 45° with the surface rested upon. The slab is first drawn, also a projector from the middle of the edge *a*; upon this is located the position of the face of the cube which is drawn by aid of the set square of 45°, the oblique sides being projected at 30° and made half the depth of the front sides. Fig. 9 is the projection of a box by the first method, to a scale of ½ in. to 1 ft.; it should offer no difficulty as it is merely an elaboration of the cube.

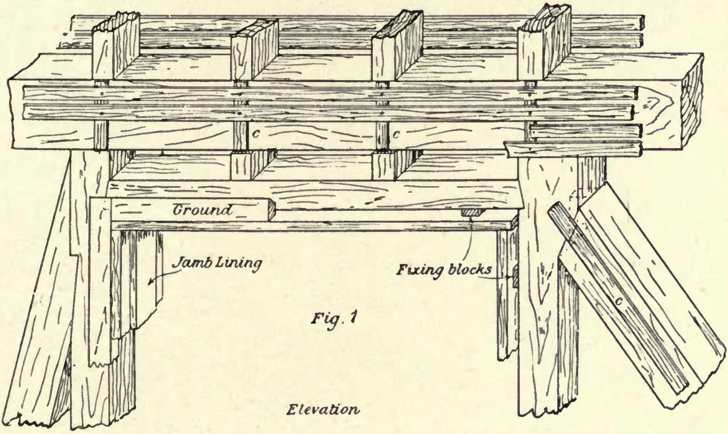
Fig. 10 is a projection of a hexagonal prism. The near surface or end is produced by using the set square of 30° to draw the two lower surfaces, marking upon them the required width, raising vertical sides at these points, making


b
b
c
a
a
Scale of Feet.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Oblique Projection—a Trussed Partition

these the same length as the first; then slide the set square forward until it reaches the ends of the vertical sides, and lines drawn therefrom will complete the hexagon. The oblique projectors are at an angle of 45°.

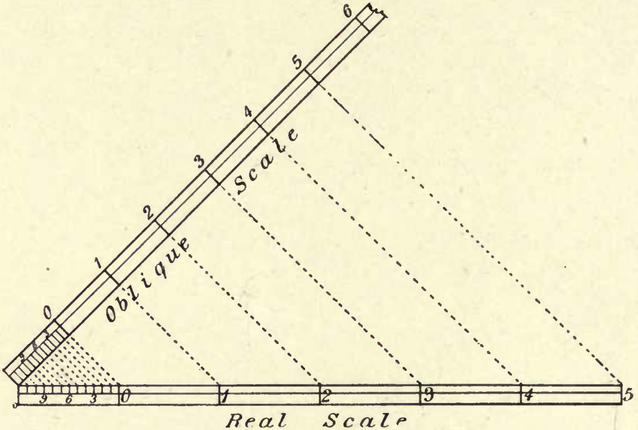
**A Trussed Partition,** such as is used to divide large and lofty buildings into apartments, is shown in oblique projection on page 104, and a portion of the head of an opening in a similar partition is shown below. The former is projected from the elevation at an angle of 30°, the latter at 45°. The opening shows linings to receive a door with portion of the architrave grounds attached to indicate method of fixing them. The cross or counterlaths *C.C.C.* are fixed to the face of the framing, to provide a space behind the ordinary laths to receive the key of the plaster.



Oblique Projection—a Doorway in a Framed Partition

The elevation in both cases should be completed in the usual manner before setting them into oblique.

**Diminished Oblique Projection.**—The author would distinguish by the above term a method of placing objects in oblique projection that he has used in his classes for some years with success. The view obtained is clear and convincing, and does not offend one's sense of proportion, as do drawings by the common method. Within well-defined limits it gives very rational graphs of polygonal and other than rectangular figures, which are difficult of representation by other methods, and it has the advantage that the oblique sides are diminished in a definite and constant ratio to the parallel sides. Moreover, no scale need be used to read the dimensions; all that is necessary to discover the dimensions of any part is to project a parallel from it to the ground or picture line, when it is at once seen in its true size, or to the same scale that the parallel portion is drawn. The method will be made clear in the description of the examples. If, however, it is preferred to use a scale for taking the dimensions, one can easily be constructed as shown above. Thus, lay down the real scale, or a full-size measure, horizontally, and from its left extremity draw a line at an angle of 45° (or whatever angle it is intended to use), and upon this line draw projectors at reverse angle, from each division upon the real scale, and a scale contructed as shown will indicate the real dimensions when it is applied to the oblique drawing.



Method of constructing an Oblique Scale

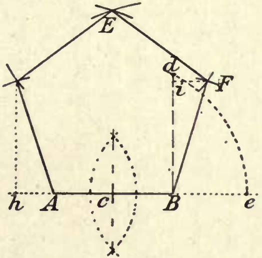


Fig.4.

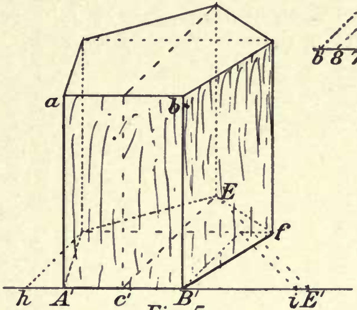

a
b
E
f
h
A'
c'
B'
iE'

Fig.5.

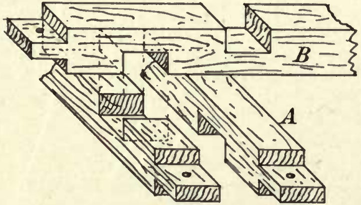


Fig.3.

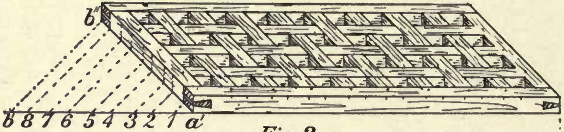

b'
8 8 7 6 5 4 3 2 1 a'

Fig.2.

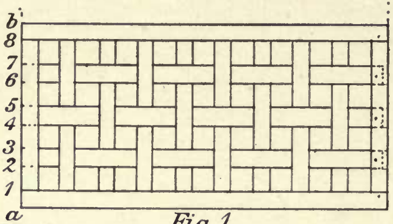

b
8
7
6
5
4
3
2
1
a

Fig.1.

Diminished Oblique Projection Examples

Figs. 1 and 2. A Ship's Grating. Fig. 3. Details of Joints. Fig. 4. Construction of Pentagon. Fig. 5. Projection of a Pentagonal Prism

Fig. 1, page 107, is the plan in orthographic projection of a wood grating or ventilator used for covering openings in floors, decks, etc. Fig. 2 is a view of the same object placed in oblique projection by the diminishing method. The front edge of the frame is drawn resting on the ground, and the ground line is produced to the left indefinitely. Project the two ends of the frame at angles of 45° with the ground line, then set off on the ground line to the left of angle *a′*, the point *b′*, equal to the width of the frame *a–b*, Fig. 1. It is perhaps unnecessary to say that this plan is only drawn for the purpose of explaining the method clearly, and that the view could be made equally well from written data. Having obtained point *b′*, project a line from it at an angle of 45°, intersecting the first drawn projector at point *b″*; this locates the back edge of the frame, and defines its width. Complete the outline of frame. Next set off the widths of the bars and spaces along the top edge as shown, also along the ground line for the end, as indicated by the figures 1 to 8; project these respectively parallel with the ends and the line *b′–b″*, by aid of the set square of 45°, and carry the latter vertically to the upper surface, when the completion of the grid will be a simple matter. The intersecting angles are to be shown as in the drawing, and a little shading introduced to give the effect of solidity; the light is supposed to come from the right hand.

**Details of the Joints** are shown in Fig. 3 by the same method, but the construction lines are removed. The piece *A* is shown beneath *B*, instead of above it, for want of space; otherwise it is relatively in the correct position. An angle of 45° is generally the best for this method of projection, but any other convenient angle may be used, if it is remembered that the diminishing projectors must always be at a similar angle reversed.

**Pentagons.**—The application of the method for projecting polygonal figures is shown in Fig. 5. It may be useful first to give a method of constructing a pentagon geometrically. Let *A–B*, Fig. 4, be the given side of the

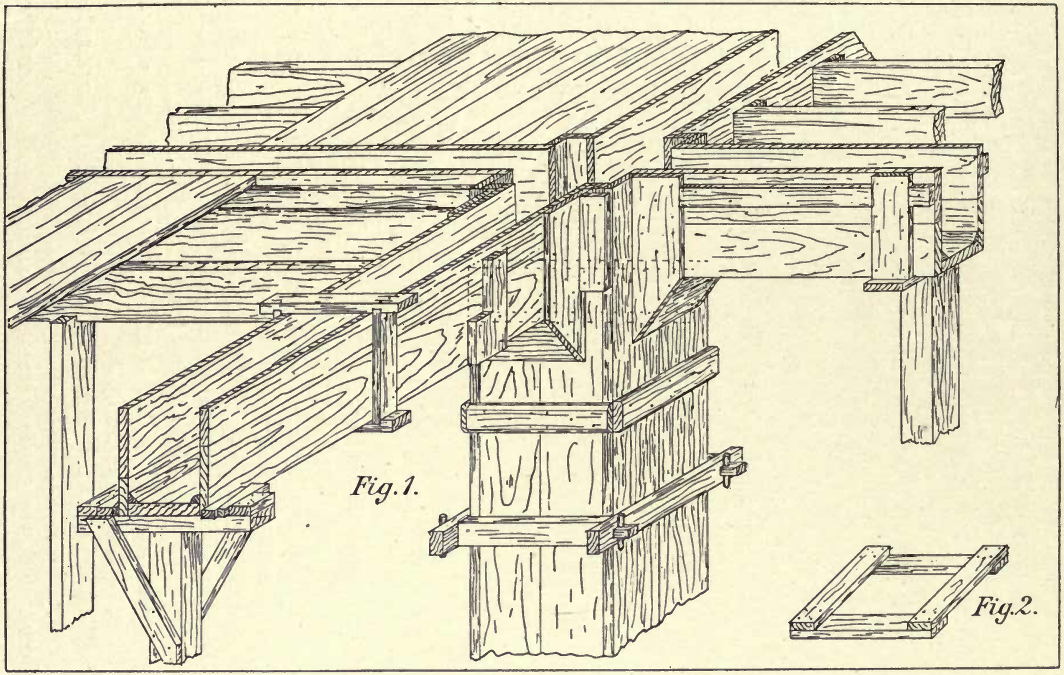


Fig. 1. Shuttering and Forms for Reinforced Concrete Work. Fig. 2. A Light Clamping Frame

pentagon. At *B*, erect a perpendicular, and make it equal to the given side; bisect *A-B*, and from its centre *c*, with radius *c–d*, describe the arc *d–e*. Then from *A* and *B* as centres, and *A–e* as radius, describe arcs intersecting in *E*. From points *A–B–E*, with radius *A–B*, draw intersecting arcs. Join up the points of intersection and the pentagon will be constructed.

**To construct an Oblique Projection of a Pentagonal Prism**, Fig. 5.—Draw the ground line, and upon it construct one face of the prism, as *A′–a–b–B′–A′*. Draw the projector *c′–E* at angle of 45°. We have next to find its length. Set the height of the pentagon *C–E* (Fig. 4) off on the ground line from *C′* to *E′*, and draw a projector from this point, intersecting the first at *E*. We have now the diminished height of the pentagon, and as all the points will be similar at the other end of the prism, erect a perpendicular (dotted) at *E*, and make it equal in length to *A′–a*. We have next to place the inclined sides in their relative position. We might do this by finding a proportional at right angles to the line *c′–E* as shown at the top end, and so locating the two side angles, but it is easier to deal with the side in relation to a right angle. Draw a dotted projector from *B′*. Next draw a perpendicular to *B–d*, Fig. 4, from the angle *F*, intersecting *B–d* in *i*. Set off *B–i* along the ground line from *B′* and draw a projector from *i*. This gives the diminished length of *B–i*, and on a parallel to the ground line through the intersection we can locate point *f*, which represents *F* in Fig. 4. Points *B′–f* and *E* can now be joined up and the two sides drawn. To obtain the opposite angle, draw a horizontal line from *f*, and intersect it by a projector from *h″*, which is made the same distance from *A′* that *h* is from *A* in Fig. 4.

**Shuttering and Forms for Reinforced Concrete Work**, page 109.—These are the terms applied to the wood moulds or casings, erected to contain and support the concrete which is poured around the iron bars and straps composing the reinforcement, until the concrete has

" set." The term " shuttering " is applied to boards which are secured together with ledges, having merely to support the concrete, such as against the face of walls or under sides of ceilings, fronts of galleries, etc. When the duty of the casing is to mould or shape the concrete poured into it, as in the case of girders and columns, it is termed " forms." Both kinds are shown in the illustration, which is given as an advanced example of diminished oblique projection.

The objects of these constructions are that they shall be economical in cost of construction, shall be readily removable without damage to the green work, and shall be strong enough to support the loads without deflection, and shall not cast or warp on the introduction of the wet concrete. Various methods and devices are used to meet these ends, and the best must be determined by individual circumstances.

As at the present time almost all that is left for the carpenter to do on modern buildings is the formation of these casings, it may not be out of place to offer a few remarks upon their construction. The wood selected should not be the roughest and commonest that can be obtained. Whilst it is not suggested that first-class joiner's wood should be used, the cost for labour in conversion and subsequent making good of defects on the face of the work will, if any rubbish is used for the forms, soon outweigh the first saving in cost of material. Dry stuff should not be used, as it will swell abnormally on the introduction of the wet concrete; shaky stuff should be avoided, but sound knots may be disregarded; loose ones will supply undesirable " keys " that will prevent removal. The fewer nails used the better. These will rust in and be unremovable, and as a consequence much of the stuff would be useless for conversion. The shuttering should not be in too large pieces for convenient handling; joints in the stuff do not matter, as the surfaces of the concrete, if not rendered, are usually rubbed, unless they are out of sight.

Forms for beams should be made so that the sides can be removed without interference with the bottom; it is often necessary to accelerate the drying by removing the side shuttering as soon as the concrete is sufficiently set, yet not strong enough to support itself, hence the soffit board and centering must be left up. For this reason the "troughs" are not nailed together, but, as shown in the foreground of the drawing, are either wedged up tightly against the bottom board or where the "panel" is not to be filled in, until the girders are set, a method often used in heavy floors, "Box cleats" are formed around the trough, letting the ends of the ledges project slightly and notching them into cross pieces. If a nail is driven into the loose piece to prevent its falling off, the head should stick out for the pincers to grip.

Mouldings or chamfers are generally made on the lower edges of girders; the shapes for these should be nailed to the bottom, not to the sides of the forms. Let the ends of the beam troughs rest upon notches cut in the column forms as shown, because the column casing should always be the last removed. A good foreman will keep these up as long as he can, to protect the concrete. The fixed ledges on the "sides" of the column casing should run over the edges of the "faces." This will keep them in right position when setting up whilst the box cleats are being fixed. These cleats are turned out in numbers from the mill, and holes bored in the tenons for the oak pins to secure them. The latter are kept in a box handy to the workman, and can be used many times over. Another form of clamp is shown in Fig. 2. These are nailed together at the angles as they are placed around the forms, but are only suitable for columns of small size or height. Near the bottom of high columns, the clamps should be made of 3 in. × 3 in. stuff bolted at the angles, as the pressure is great at the bottom of a column, especially if it is filled in quickly.

Most of this casing is shown as inch stuff, but the thickness will depend upon the nature and size of the beams, etc. The props must be placed pretty closely together, so that no sagging takes place. The bearers carrying the panels are shown as 2 in. × 6 in. floor joisting, and the props should be notched over them to prevent being knocked aside. This is better than nailing, for the subsequent removal. The panel shuttering should not be fitted tightly; allowance should be made for swelling.

In drawing the example, get in the main features or outlines first, leaving details until later.

The column, being the principal object in the drawing, may well form the starting-point, then the four troughs.

Portions have been purposely omitted from the example to show the construction clearly, and, apart from the numerous details which simply require carefulness on the part of the draughtsman to place correctly, anyone who has worked through the previous examples should be able to reproduce this.

# CHAPTER VIII

## PERSPECTIVE OR RADIAL PROJECTION

Definitions and Principles. The Limiting Cone of Visual Rays. A Simple Method of producing a Perspective from the Plan—its limitations. Examples—with instructions for drawing. A Rectangular Frame. A Stone Pedestal. A Large Chest. A Pedestal or Office Table. Method of determining the Vanishing Planes—when a vanishing point is not available. Obtaining the Perspective Reduction when Vanishing Points are out of limit

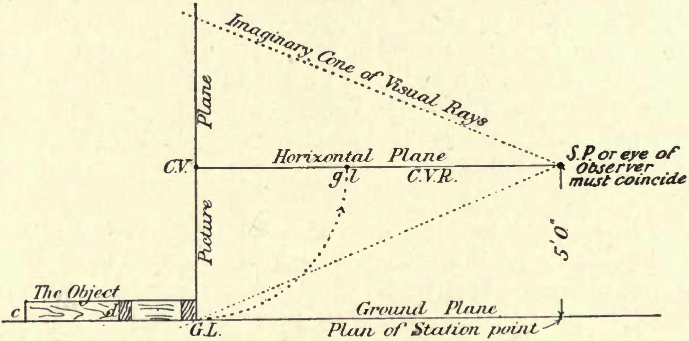
THE method of perspective projection here described is a variation of the more elaborate process used by artists in preparing pictures. The principles involved are the same, but the method of application is simplified. Of course the method has its limitations, but it has sufficient scope to embrace all the requirements of the student of technical drawing. The limits of this book compel restriction to a few elementary examples. The purpose of perspective drawing is to represent objects as they appear to the eye when viewed in certain defined positions and distances from the observer, which is the essential difference between this class of drawing and the others dealt with in this book, wherein no consideration is given to the position or distance of the object represented.

**Definition of Terms and Symbols used in Perspective.**—It is assumed as a principle in this form of perspective drawing that rays of light pass in straight lines from every portion of the object to the eye of the observer, forming, as it were, a cone of rays, the base of which contains the object, the apex of the cone being in the eye of the observer ; if, then, it is conceived that a transparent plane is interposed between the object and the person viewing it, and that the rays of light passing through the plane are connected by a series of lines on the plane, it will be obvious that we should thus get a representation of the object upon the plane, differing in size only, according to the distance the plane is placed from the eye.

This imaginary plane is the one dealt with in making a perspective drawing, and it is termed the picture plane, usually denoted by the symbol, P.P. Obviously, the nearer the picture plane is placed to the object the larger will be the view obtained upon it; also the farther the observer stands from the object the smaller will it appear to him. We know by experience that when a flag is placed at the top of a tall mast it looks very much smaller than when at our feet on the ground.

Also we know by experience that if we observe an object obliquely we get a different view or impression upon the retina of the eye than we do when it is seen from directly in front. Now as the purpose of a perspective drawing is to represent the object as it *appears* to a person in a certain position and at a specified distance, it will be understood that the first thing to be done is to map out these various data upon the drawing, which we can then proceed to make in conformity with them.

The necessary data for commencing the drawing are indicated by the diagram on page 116, which is a section, or end view, at right angles to the *P.P.* of the drawing shown on page 117. As the object of this method is to simplify procedure, we make two arbitrary assumptions at the start: first, that the ground plane (*G.P.*) is 5 feet below the horizontal plane (*H.P.*), the reason being simply that 5 feet is the height of the average person's eye above the ground. The second assumption is that the nearest angle of the object touches the picture plane (*P.P.*). These assumptions enable us to set down at once on the paper the horizontal line (*H.L.*), which is an edge-view of the plane in which lie the station-point (*S.P.*,) and the central visual ray (*C.V.R.*), which is another name for the axis of the cone of rays before referred to. The elevation of the *C.V.R.* in the perspective view is called the centre of vision, *C.V.*, see page 117. We can then draw the *G.L.* 5 ft. below and also lay down a plan of the object with a plan of the *P.P.* touching one angle, and we can draw a plan of the *C.V.R.*


Imaginary Cone of Visual Rays
Plane
Picture
C.V.
Horizontal Plane
g.l
C.V.R.
S.P. or eye of Observer must coincide
5'0"
The Object
c
d
Ground Plane
G.L.
Plan of Station point

Section of Diagram, p. 117, perpendicular to Picture Plane

which must be at right angles with the plan of the *P.P.* Next we fix on plan the position of the *S.P.* from the *P.P.* at such a distance from the object that a cone of visual rays, having a vertical angle of about 40° at the *S.P.*, will entirely envelop it (see Fig., page 116). The reason for limiting this angle is that if a much wider angle be adopted there will be an appearance of distortion in the resulting perspective view. The student should make a few experiments upon this point. Finally the vanishing points (*V.P.*) have to be located.

These are points to which parallel lines appear to converge. If the parallel lines are horizontal they will appear to con-

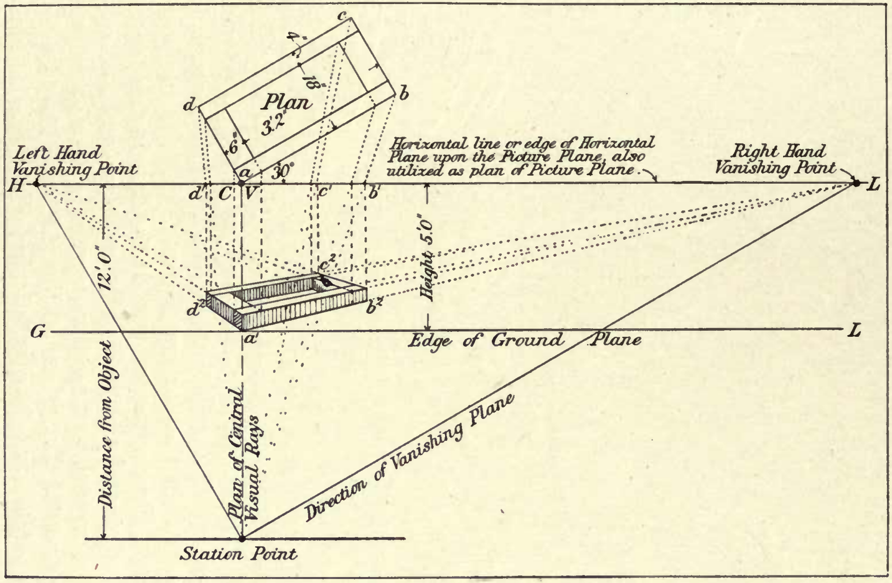

c
4"
18"
d
Plan
3'2"
b
6"
a
30°
Horizontal line or edge of Horizontal Plane upon the Picture Plane, also utilized as plan of Picture Plane.
Left Hand Vanishing Point
H
d'
C
V
c'
b'
Right Hand Vanishing Point
L
12'0"
Height 5'0"
c²
d²
b²
G
a'
L
Edge of Ground Plane
Distance from Object
Plan of Central Visual Rays
Direction of Vanishing Plane
Station Point

Diagram illustrating Principles of Practical Perspective verge to points upon the horizon—that is to say, in the *H.L.* If they are inclined to the horizontal they will converge to points above or below the *H.L.*, as the case may be. If they are parallel to the picture plane they are represented as parallel in the perspective, though they only remain sensibly parallel within the limits of the cone of restricted angle above referred to. In the form of perspective here described, only horizontal and vertical lines are dealt with; the latter, being of course parallel with the *P.P.*, remain parallel in the perspective view. The *V.P.'s* for horizontal lines are found by means of the plan as explained below.

With the above outline of the theory as explanation, we can now proceed to describe in detail the construction of the several drawings (pages 117, 121, 123, 125), each involving different requirements. It will be seen that the examples given combine in each case a plan, which is set out in its required relation to the *P.P.*; an elevation, where necessary to give dimensions not shown by the plan, and the perspective view itself, which is partly projected directly from the plan and partly set up by means of dimensions taken from the elevations. One and the same line does duty for the plan of the *P.P.* and for the *G.P.* in the perspective view—that is, we, in effect, when making the perspective drawing, assume that the picture plane is rotated into the horizontal plane, as indicated by the dotted arc in the diagram, page 116; where *G.L.*, which is also the plan of the picture plane, reaches *g.l.* in the horizontal plane. This is the position shown on the perspective part of the drawing on page 117.

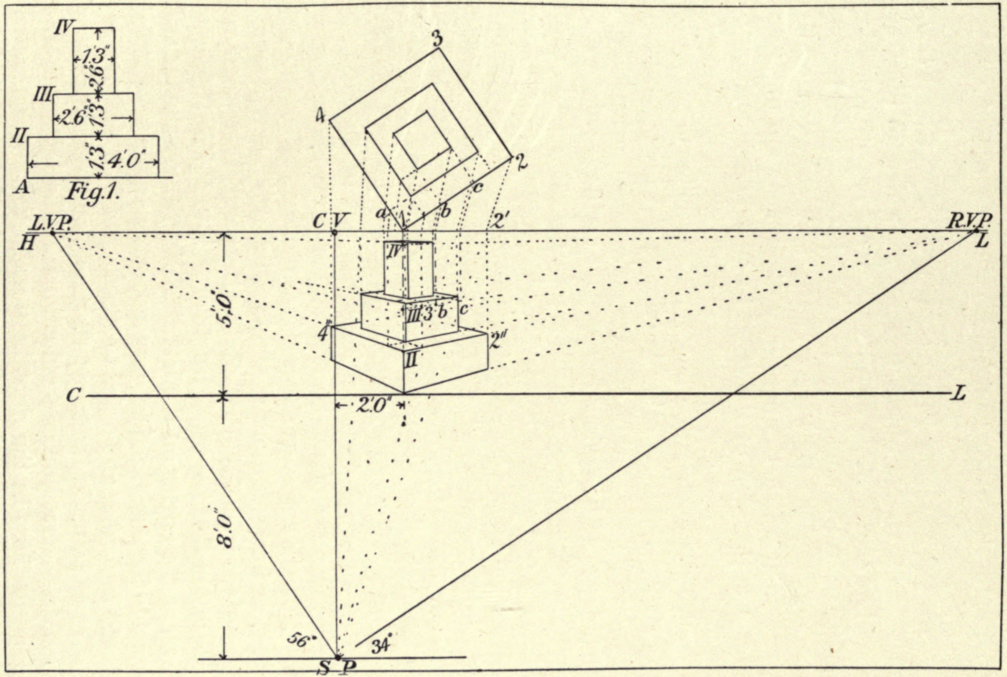
The plan and the lines radiating therefrom to the *S.P.* could, of course, be set out on a separate piece of paper, and the horizontal dimensions on the *P.P.* could be transferred to the perspective view by "ticking-off": this is the usual procedure in office work with more complicated drawings, but the beginner will find this method of drawing the plan adjacent the perspective view and the obtaining the dimensions by projection much clearer.

**To draw in Perspective a Rectangular Frame** lying on the ground 12 ft. distant from the observer, with its salient angle directly opposite, and its sides making angles of 30° and 60° respectively with the picture plane (see page 117).

Commence by laying down the plan to the given dimensions with its right side at an angle of 30° to the $\left\{\begin{matrix}P.P.\\H.L.\end{matrix}\right\}$ and touching the latter in point *a*, which becomes the centre of vision. Project this point to a line drawn parallel to the $\left\{\begin{matrix}P.P.\\H.L.\end{matrix}\right\}$ distant 12 ft., to scale, locating the station-point thereon. From this point draw lines parallel with the sides of the frame *a–d* and *a–b*, intersecting the *H.L.*, which locate thereon the left-hand and right-hand vanishing points respectively. Draw the ground line *G.L.* 5 ft. below the *H.L.* and parallel therewith; this locates the picture plane, upon which we can now produce the projection. From each corner of the frame *a–b–c–d* draw projectors to the *S.P.*, stopping them when they reach the horizontal line upon the picture plane, as shown at *a–b′–c′–d′*. Drop perpendiculars from these points to the ground line. It will be remembered that the angle *a* is to be in the line of sight and upon the ground, therefore, where the line drawn from *S.P.* to *a* intersects the ground will be the position of *a′*. Next draw, from point a′, lines to the two vanishing points, and the intersections of the projectors with these; in points $b^2$, $d^2$ and $c^2$ locate the corners of the frame upon the ground. The respective heights or verticals at these points are obtained by setting up the height or thickness at *a′* and drawing lines to the vanishing points as shown. In like manner any other point in the plan is first brought to the horizontal line, then projected to the ground and its position located upon the vanishing planes.

**A Stone Pedestal** in three tiers, with its sides making angles of 34° and 56° respectively, with the picture plane and its nearest corner 2 ft. to the right of the spectator and 13 ft. away from him, is represented in perspective projection on page 121. An elevation is given in Fig. 1 to indicate dimensions.

Commence by drawing the *H.L.* in a convenient position near top of sheet and the *G.L.* 5 ft. distant therefrom, and a parallel at 13 ft. distant, on which mark the station-point *S.P.* Draw a perpendicular from this to the *H.L.*, locating the *C.V.*, and mark off along the *H.L.* point 1, two feet to the right. From this point set out the sides of the lower block, making an angle of 34° and 56° with the *H.L.*, and complete the plan as shown. Locate the vanishing points as before by lines drawn from *S.P.* parallel to the sides of the plan. Draw projectors from each angle of the plan towards the station-point, but stop at *H.L.* Drop a projector from point 1 to the ground; this locates the salient angle of the lower slab, and on it measure up the height of point *II.* (see Fig. 1). Draw lines towards the vanishing points and intercept them by projectors from points 2 ft. and 4 ft. upon the horizontal line, thus locating the position of the distant corners of the block in the picture. To obtain the heights of the second block we must mark off the heights as given in Fig. 1 upon the perpendicular 1–*II.*, which lies in the picture plane, and therefore shows real heights; then draw lines to the left and right vanishing points which, intercepted by the vertical projectors from the said points on *H.L.*, will show the heights those points reach in the distance. A few of the projectors from the plan are taken across to the *S.P.* to indicate the direction, but these, of course, are not dealt with below the *H.L.* It will be noticed that the sides of the second block which stand within the lower one are produced by means of dotted lines to the face of the lower block, and thence projected to the *H.L.*; this is necessary in all cases where parts of the object stand back from the main face. When they are located upon this face in the perspective projection they must be projected back again into their relative


IV
1'3"
2'6"
III
2'6"
1'3"
II
1'3"
4'0"
A
Fig.1.
3
4
2
a
b
c
2'
L.V.P.
H
C V
R.V.P.
L
IV
III
3
b
c
4"
2"
II
5'0"
C
L
2'0"
8'0"
56°
34°
S P

Example of Perspective Projection—a Stone Pedestal position to the face by means of projectors taken from the points to the other vanishing point, as shown on the drawing.

**The Perspective Projection of a large Chest** (page 123).—This simple object has been selected to illustrate a method of dispensing with the use of one or both vanishing points when the angle is so low that it takes these beyond the drawing sheet. Fig. 1 is the end elevation of the chest from which the necessary dimensions are obtained, Fig. 2 is the plan of the chest in its relative position to the observer, and Fig. 3 is the perspective projection. To simplify the explanation one vanishing point is shown on the right hand; the other is outside the picture.

We will assume that the projection has been made in accordance with previous instructions up to the point where position of the two vanishing points has to be located. The plan of the right-hand vanishing plane is drawn from the station-point parallel to the right-hand side of the plan, and its intersection with the *H.L.* gives the *R.V.P.* A line is also drawn from *S.P.* parallel to the left-hand side of the plan, so far as the limits of the paper allow. At any convenient point in this line, as *A*, erect a perpendicular to the *H.L.*, and at an equal distance from the line of sight on the right vanishing plane, erect a similar perpendicular, as at *B*. Now the angles on either side of the line *P.V.* or *S.C.* are alike, and any divisions of the base line *P.V.*, drawn to the apex of the triangle *R.V.P.*, divides the parallel *B* in the same proportion that the whole length of *B* is to *P.V.* It follows that, as the angles on the left side of *P.V.* are similar and equal to those on the right, any proportions upon the parallel *A* will be similar and equal to those upon *B*, if drawn from the same points in the base; therefore, all that is necessary to obtain corresponding reductions in the left vanishing plane to those in the right is to make the divisions on *A* equal to those upon *B*, and draw lines to those points from the heights marked upon the vertical angle of the object

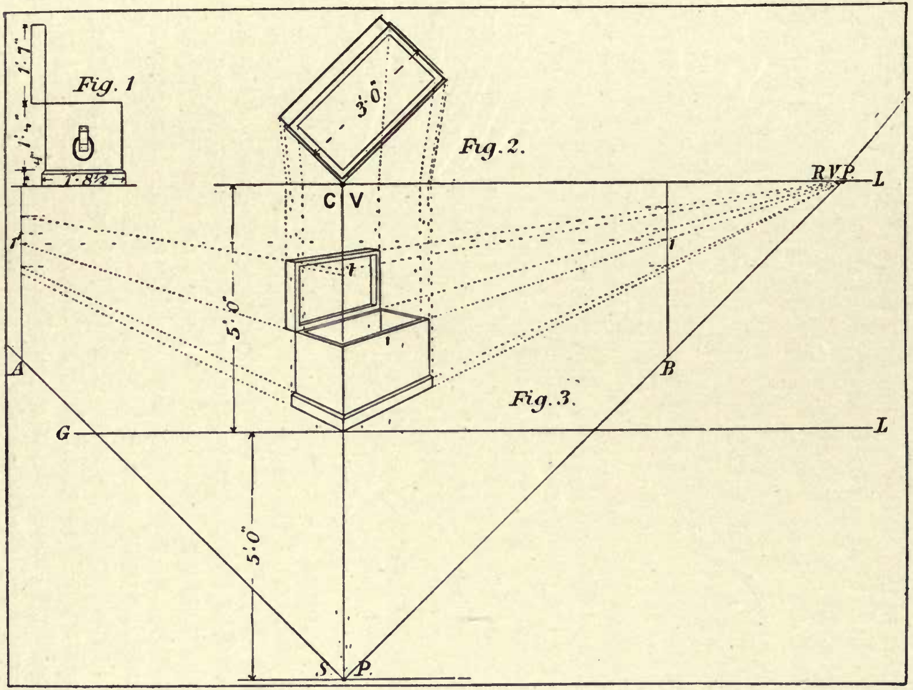


Fig. 1
1'7"
1'4"
4"
1'8½"
Fig. 2.
3'0"
C V
RVP
L
1
1
1
B
A
5'0"
Fig. 3.
G
L
5'0"
S
P.

Method of projecting with one Vanishing Point which touches the picture plane. For example, take the point 1 in line *B*. Where the projector from the top edge of the chest passes through it, draw a horizontal line from this point to line *A*, intersecting it at point 1′, and a line drawn from the front top angle of the chest through this point will give the angle of vanishing projector as correctly as if it were drawn to a vanishing point. All the other points found on *B* can be projected in like manner to *A*.

**The Pedestal Table** shown in plan and elevation in Figs. 1 and 2, page 125, and in perspective in Fig. 3, is an example of the method of making the projection when the vanishing point is too distant to find and the angles of the plan are unequal. In this case the plan makes angles of 30° and 60° with the horizontal line, and the object is 13 ft. from the observer. In the previous case, where one *V.P.* was missing, the position of the plan enabled us to form two proportionate triangles alike on each side of the common "base" line. Here that method cannot be followed, but we can proceed to locate the left vanishing point which lies within the picture, and so obtain a triangle in which we can arrange a smaller one, as at *A–a, L.V.P.*

We can, with this as a base, construct a similar triangle on the other side, which shall bear the same relation to the hypotenuse of that triangle as *A–a* does to the line *S.P.–L.V.P.* Then all reductions obtained upon *A–a*, if transferred to the proportionate parallel *B–b*, will give proper reductions for that side of the picture, and we shall obtain exactly the same lines as if we had taken them directly to a vanishing point upon that side.

Proceed to lay down the plan, the *H.L* and *G.L.*, and the station-point, to given data and draw the plans of the vanishing planes as far as possible, and parallel the respective sides of the plan. Anywhere on *L.V.P.–S.P.* erect a perpendicular to the *H.L.*, as *A–a*. Draw a parallel to the *H.L.* from *A*, intersecting the right vanishing plane in *B*; erect a perpendicular to *H.L.*, and transfer all reduced

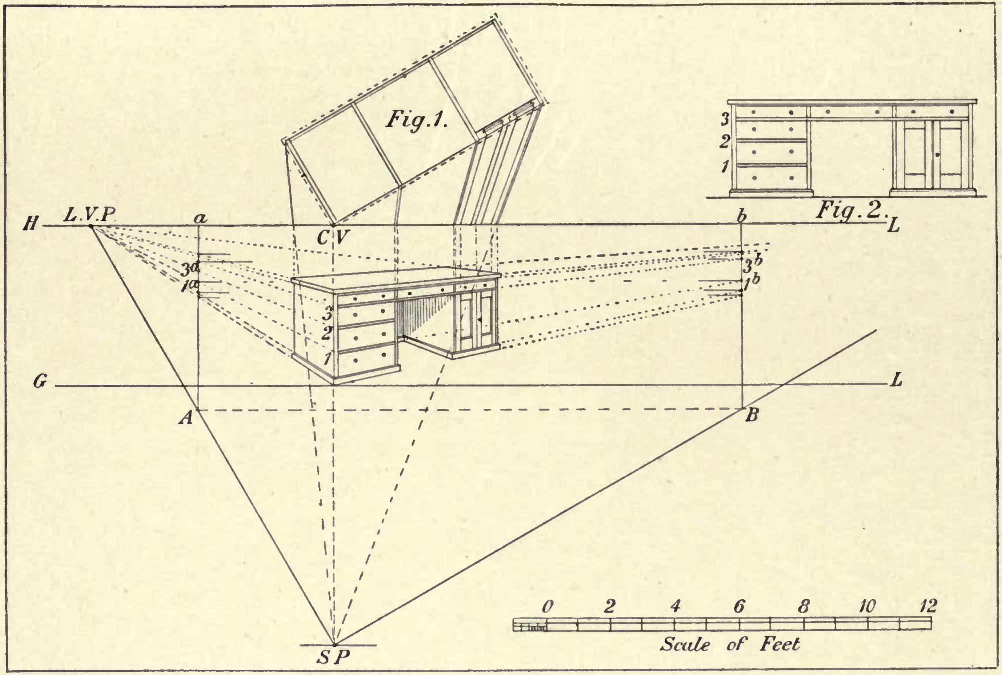


Fig.1.
Fig.2.
3
2
1
H
L.V.P.
a
CV
b
L
3a
1a
3
2
1
3b
1b
G
L
A
B
SP
0
2
4
6
8
10
12
Scale of Feet

Example of Perspective—an Office Pedestal Table

Fig. 1. Plan. Fig. 2. Elevation. Fig. 3. Perspective Projection

points on *A–a* to *B–b*, as shown, and thus obtain direction of vanishing lines upon that side.

The completion of the perspective view will now proceed as described in previous cases, the heights of the drawers, plinths and door rails being obtained from the elevation, Fig. 2. A scale of feet is provided by aid of which the sizes may be read off.

## CHAPTER IX

## FREEHAND DRAWING OR SKETCHING

Definition of Freehand—its uses to the artisan and draughtsman. How to draw Curves. Manipulation of the Pencil. Plotting Points. Examples—copying a moulding, a cabinet screw driver, cylinders. A Stone Baluster. A Screw Wrench. Use of Squared Paper—enlarging and diminishing drawings. Sectional Tracing Paper—how to use it. Stone Carving for a Window Head. Various Hinges—description of their uses and sizes: butt, back flap, table and desk hinges, trestle, parliament, pew, counter flap, hook and eye, Collinge, cross garnets, floor springs

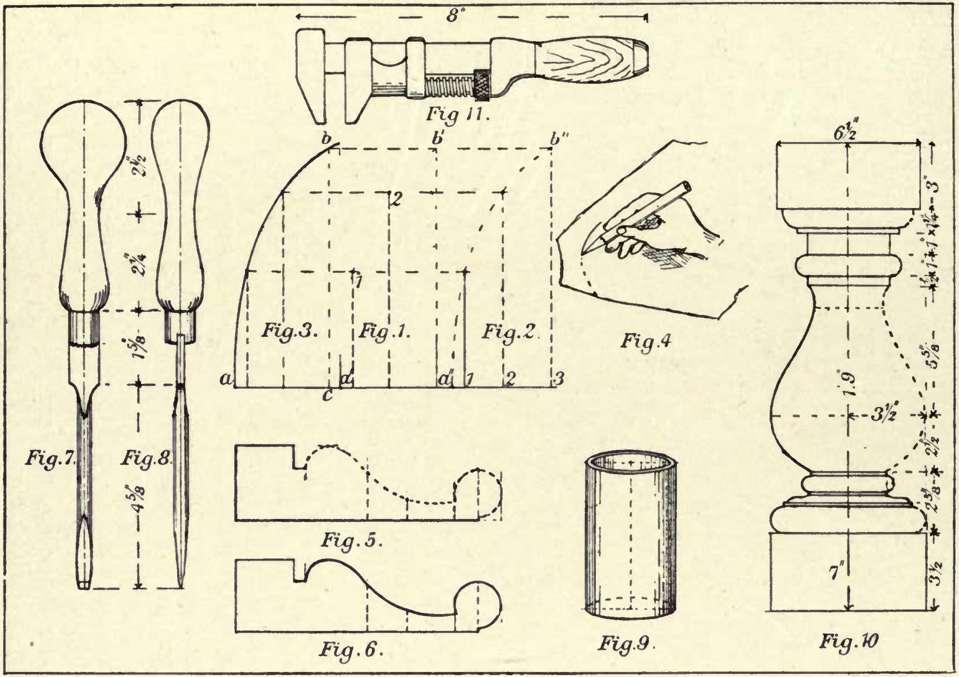
THE term "freehand" has been defined in Chapter I., and it is only necessary to say here that what is meant and described under that term is the production by pen or pencil of those parts of a technical drawing that cannot profitably be made by means of instruments. There are many small and subtle curves met with in technical drawing that can be quickly and well put in by the unaided pen or pencil if the draughtsman educates his hand to that end, and it is to assist him in acquiring this power that these instructions are given. Straight lines can be better and more profitably produced by mechanical aids, and though the power to draw a straight line a foot long entirely without the help of a ruler, etc., may be of value on rare occasions, it seems to the author that time can be better spent than in attempting to acquire such exceptional skill, and he prefers to use instruments for the purpose himself. The ability to draw a firm regular line, showing the profile of a moulding, or to sketch some small object we wish to describe is of value to every artisan, and not the least to those who aspire to positions of authority or supervision.

The methods here described are those used by the author for many years.

**How to draw a Curved Line.**—The beginner generally starts off to draw a curved line by gripping the pencil rigidly between thumb and fingers in a nearly upright position, and, with stiffly set wrist, proceeds to trail slowly across the paper, in as near as may be the direction desired. Invariable result : a weak, wobbly and irregular line, which, if unadvised, he disgustedly rubs out and begins afresh in the same manner ! Nothing else might be expected, the tense muscles causing continual vibration of the hand.

Quite the opposite of the above method is the correct one. The pencil should be held as lightly as possible, much as one does in writing, with the fingers and thumb working in unison, not counteracting or checking each other. The particular slope or angle of the pencil is of less moment, and will vary with individual habits, also, to some extent, with the size of the curve to be drawn. For large, bold sweeps, an angle as shown in Fig. 4, page 129, is suitable, very similar to that of a pen in writing. Smaller curves will need the pencil held more uprightly, so that the point shall not interfere with the view. The hand should rest lightly on the table, and the arm should not to any extent participate in the movement. The drawing should be made by the hand working on the heel as a pivot and finishing its movement at the wrist. Do not attempt to take the curve farther than one sweep of the hand will carry, but, having reached that point, move the hand and start afresh.

Suppose it is desired to draw a curved line as *a–b*, Fig. 3, some guide points are necessary to the novice, and these may simply be plotted in as points, through which it is desired the curve to pass, or they may be projected from a given drawing, such as points in the plan of a circular sash, for which a face mould is required. The drawing, then, in its preliminary stage, will be as Fig. 1 : *a′*, 1, 2, *b′* being the points the curve must pass through. Next put in a series


8"
Fig 11.
b
b'
b"
2
1
a
c
d
d'
1
2
3
Fig.3.
Fig.1.
Fig.2.
Fig.4
2½
2¼
1⅝
4⅝
Fig.7.
Fig.8.
Fig.5.
Fig.6.
Fig.9.
6½"
3"
1¼
1
1
½
5⅝
1'9
3½"
2½
2⅝
3½
7"
Fig.10

Freehand Drawing

Figs. 1 to 3. Successive Steps in drawing Curved Lines. Fig. 4. Method of working. Fig. 5. Preliminary Sketch for Fig. 6. Fig. 6. Section of a Moulding. Figs. 7 and 8. A Cabinet Screwdriver. Fig. 9. A Hollow Cylinder. Fig. 10. A Stone Baluster. Fig. 11. A Screw Wrench of dashes or points between the main ones as shown by Fig. 2.

The middle point in each section should first be put in so that the general appearance of the curve may be judged; having obtained these satisfactorily, put in others as close as may be considered necessary; in fact, the whole curve may be dotted-in this way without much departure from truth at first attempt, but if correction is necessary, it is easy to erase the offending dot. Next proceed to line-in as shown in Fig. 4, commencing at the right hand and joining up the dots, not by short steps, but by a bold sweep of the pencil, about 1½ in. in length. If a few "trial" sweeps are made just above the paper, the hand will get into the correct swing.

Probably at the first attempts the junctions will not flow into each other and the joints will be plainly seen, but after a little experience it will be possible to carry the hand forward whilst marking the line and so get a firm, continuous one without visible junctions.

**To copy a Moulding**, Fig. 6.—The given section was drawn mechanically—that is, with rules and compasses—but the copy (Fig. 5) is entirely freehand—*i.e.* the original of this print was so drawn.

It is shown partly finished to indicate the method of procedure. Draw in the straight lines for back and bottom of the moulding, and set off the extremities of the moulded part as shown in dotted lines. Next draw a series of similar perpendicular lines on each drawing, spacing them the same distance apart in each.

Measure the height of each upon the original and set off heights upon the copy; thus a series of points will be found through which the curve may be drawn. If the spaces are too wide for the eye to carry the line, dot in intermediate points, as advised above. You may or may not use instruments for the perpendiculars and measurements, according to the degree of accuracy required; it is quite pedantic to insist on every construction line being drawn freehand.

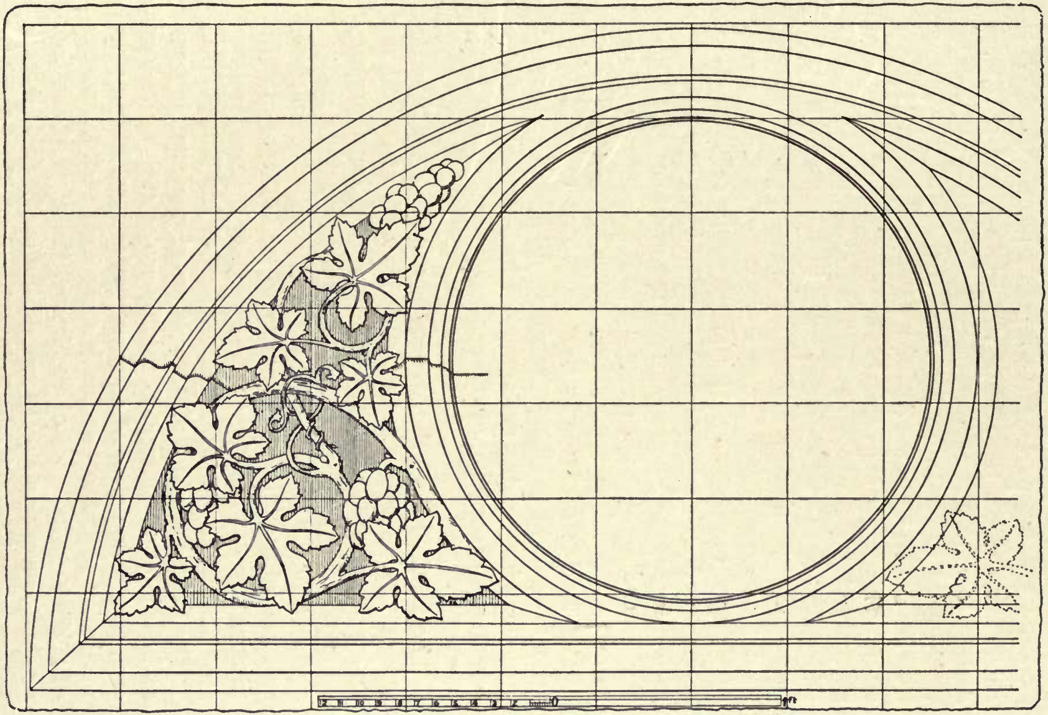
**The Cabinet Screwdriver**, Figs. 7 and 8, will afford excellent practice in " balancing "—that is, making the opposite parts symmetrical or alike on each side of a centre line. This line should first be drawn, then horizontals at various points of chief departure in the curves, and dimension points marked upon them. These will form the main guide points, and others can be placed between, until sufficient are obtained to complete the curves. The ends of the ferrule are curved, to convey the impression of roundness, which is further suggested by the shade lines. These will be referred to in the next illustration, Fig. 9, which is a **Hollow Cylinder** or pipe as viewed when standing upright just below the level of the eye. Draw the central or axis line joining the centres of the two ends ; at the extremities, draw lines at right angles to the axis. These will be the diameters of the ends and the correct width or diameter should be ticked off thereon, and the two sides of the cylinder drawn. The true shape of the cylinder is a circle, but, as stated in a previous chapter, a circle viewed at any other angle than a right angle to its plane will be seen as an ellipse, the minor axis of which varies as the angle. We need not trouble to draw this axis and plot the curve geometrically as, if the drawing is approximately correct, it will convey the impression intended. Mark a series of points equally on each side of the diameter lines and draw in the curves ; avoid making the ends too pointed, and make the lower ellipse slightly wider than the upper, as, being lower, more of the plane can be seen. The effect of roundness is given by drawing a series of straight lines from about one-quarter of the width to the edges, gradually increasing their distance apart as the middle is approached. This gives the appearance of light upon the near portion, and a gradually increasing shade as the parts recede.

**A Stone Baluster**, Fig. 10, is another simple exercise in symmetrical figures. One-half shows the preparatory steps and the other half the completed drawing. The dotted line drawn parallel with the centre is merely a convenience for marking the dimensions. The central line should first be drawn, and then the various horizontals at suitable distances; upon these the widths of the parts should be ticked off equally on each side, and the profile of the turned parts drawn in.

**The Screw Wrench** (Fig. 11) will be found a rather more difficult subject. The thread of the screw and the lines indicating the purfling or milling of the thumb-nut will test the student's accuracy in drawing parallel lines; the latter should be drawn closer together as they approach the edges to give the effect of roundness. Four faint lines should be drawn, two for the bottom of the thread and two for the tops or outside, and after the threads are spaced out and drawn across at a slight inclination, the intermediate parts representing stem and top of each thread should be lined in. A central line may be drawn through the handle and back bar, and the edges set off equally on each side and the jaws drawn perpendicular to it.

**The Use of Squared Paper**, or the ruling of lines forming squares upon the drawing, is a device that will be found of assistance in making more elaborate freehand drawings, such as the masonry details shown on page 133 opposite; also for enlarging or diminishing a drawing proportionately. In the drawing office, tracing paper with lines ruled in squares of suitable dimensions is generally used. A sheet is secured over the drawing to be copied, the lines that are printed on it breaking the drawing up into a number of parts with location points, where the lines intersect the outlines of the drawing. If the drawing is to be copied to the same size, a series of squares of similar size are ruled in pencil over the drawing paper, and the various points ticked off upon it just as they occur on the original. Each line is numbered similarly on both sheets to assist in identifying the points, and, when a sufficient number are located, the outline can be completed by freehand.

When it is desired to enlarge or reduce the copy, appropriate size squares are drawn on the sheet to the desired

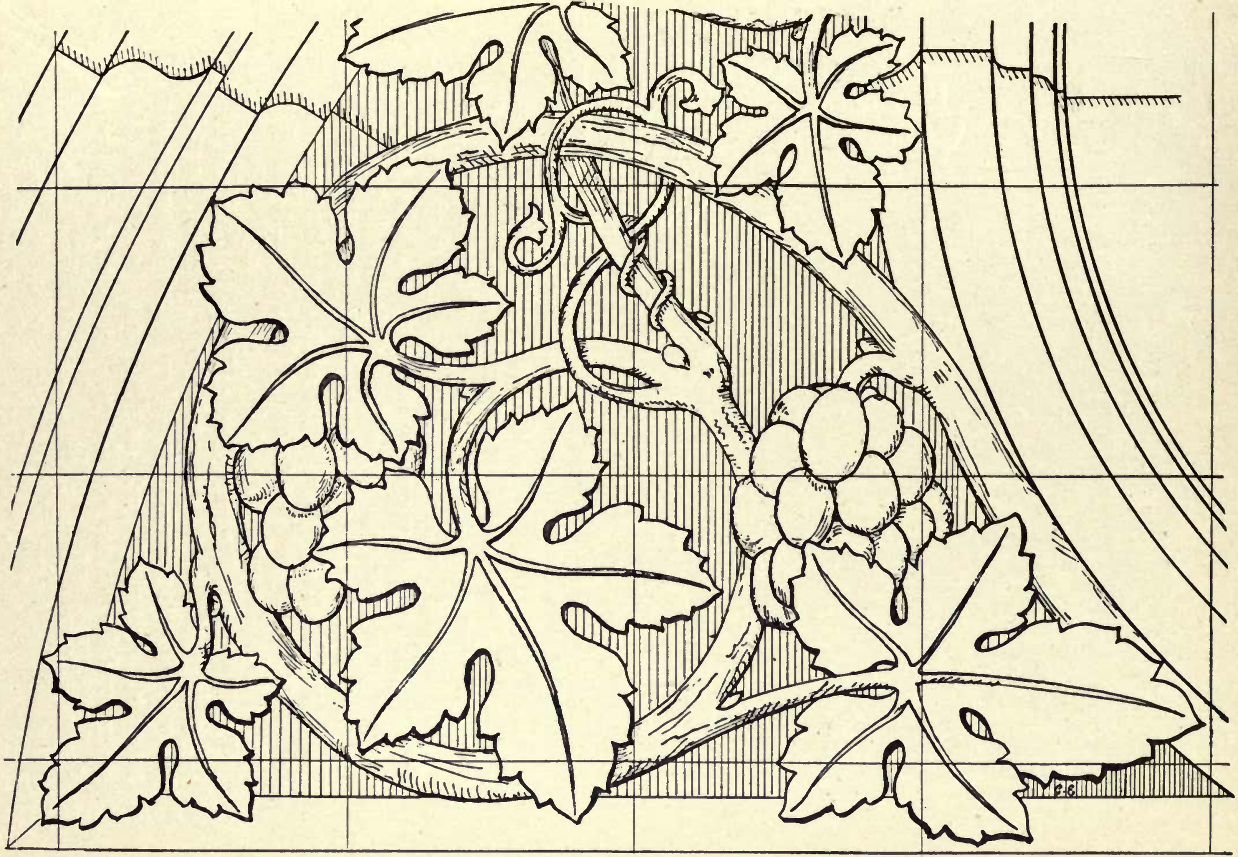

12 11 10 9 8 7 6 5 4 3 2 1 0
1ft

Masonry Details—a Carved and Moulded Window Head proportion. Thus in the drawing, page 135, the carved spandrel forming part of the window head, page 133, is enlarged to treble the size of the original, and if it were desired to reduce it to, say, one-third the size, the squares would need to be drawn one-third the size of the squares that are drawn upon the original, or upon the tracing paper used. This paper is procurable at the drawing instrument shops, under the name of sectional drawing and tracing paper, and it can be obtained ruled in squares from $\frac{1}{16}$ in. to $1\frac{1}{2}$ in. The smaller rulings on drawing paper are also used for making drawings to scale without the necessity of using "scales"—*e.g.* if the paper is ruled in $\frac{1}{8}$ in. squares a drawing may be made upon it to scale of $\frac{1}{8}$ in. to one foot, each square representing one foot, and a line, say, extending over six squares would represent 6 ft. and so on.

**The Series of Hinges** shown on page 137 will afford good exercise in freehand drawing. All the necessary instructions for copying are embodied in the previous notes, but a brief description of the various types illustrated may be useful.

**The Butt Hinge**, Fig. 1, page 137, is probably the commonest; it is made in various sizes from $\frac{1}{2}$ in. to 6 in. long, and is used for a great variety of purposes, but invariably upon the edges of the parts to be hinged; thus the two "edges" of the hinged surfaces come together when closed and are said to "abut" squarely to each other, hence the generic name of the hinge, distinguishing it from the types that are fixed upon the surface or face of the hinged parts.

The flanges or wings of the butt are always sunk in flush, and the joint or "knuckle" usually projects, that the door, etc., may swing clear of adjacent projections, but in some particular cases the knuckle is sunk flush with the surface of a bead on the edge of the frame, the edge of the door or shutter working closely around the bead. This method is termed by joiners "close-joint" hanging. The details of both methods are fully described in the author's work on



Use of Squared Paper in copying Drawings—Example of Enlargement

Practical Joinery. Butt hinges are made of cast-steel, wrought-iron, cast and rolled brass and gun-metal.

**The Projecting Butt**, Fig. 2, is made much wider than the average, and the projecting portions are thickened to improve the appearance. They are used where there is some large moulding or other projecting part adjacent to the door which it is required to fold upon. The example shown is further strengthened by hardened steel bushes upon the working surface, the remaining portion of the hinge being usually brass or gun metal.

**The Back Flap**, Fig. 3, though of somewhat the same appearance as the butt, belongs to the surface type. It is chiefly used upon shutters or similar objects which are not sufficiently thick to accommodate butt hinges upon their edges. Some fastidious people require it sunk flush with the surface, but strength is thus sacrificed to appearance. The wings taper as shown in the plan, and they are always wider than long. They obtained their name because originally they were made for the back, or inner flaps of boxing shutters, butt hinges being used on the front flap, which was made thicker to provide sunk panels.

**The Table Hinge**, Fig. 16, is a special form of back flap used in hinging the flaps or leaves of tables. The two points of difference are, that the joint is so formed that the wings will open back square to each other, consequently the knuckle projects upon the back surface instead of the front or countersunk side, which is sunk flush with the table top, thus allowing the brackets to pass freely underneath. The wings are of different length, or rather width; this is necessary because one has to bridge the hollow in the edge of the flap as shown in the sketch.

**The Bagatelle Strap or Desk Hinge**, Fig. 4, is a small brass hinge of the butt type, with wings abnormally wide in comparison to their length. They are used upon narrow margins to openings, such as desk flaps, bagatelle table covers and the like, are made of cast-brass, and in sizes from 1 in. × $\frac{5}{16}$ in. to $2\frac{1}{2}$ in. × $\frac{11}{16}$ in.

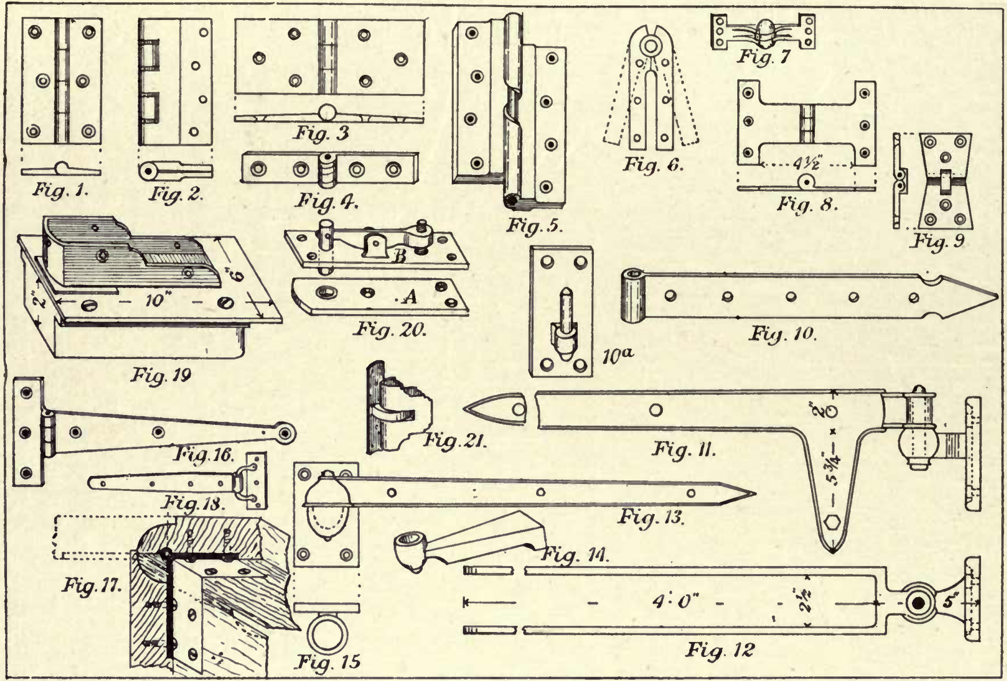


Fig. 1.
Fig. 2.
Fig. 3
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7
4½"
Fig. 8.
Fig. 9
2"
10"
6"
Fig. 19
B
A
Fig. 20.
10a
Fig. 10.
Fig. 16.
Fig. 18.
Fig. 21.
Fig. 11.
2"
5¾"
Fig. 13.
Fig. 14.
Fig. 17.
Fig. 15
4' 0"
2½"
5"
Fig. 12

Freehand Examples—Door Hinges and Springs

**The Rising or Helical Butt**, Fig. 5, is generally made of polished brass, with hard steel bearings. They vary in size from 3 in. to 6 in. long, and are used for doors that have to pass over thick carpets, lifting the door about $\frac{3}{8}$th in., when it is full open. Of course the door will not open so far back as the hinge is shown in the drawing ; these butts are made " handed." The one shown is for a left-hand door—*i.e.* a door hung with the lock to shoot towards the left hand of the person viewing the face of the door.

**The Trestle Hinge**, Fig. 6, used for hinging builders " trestles " or scaffold steps, is made in wrought and malleable iron in sizes from 6 in. to 14 in. They are fixed upon the surface of the frames and are of the strap type.

**The Parliament or Shutter Hinge**, Fig. 7, has extended wings and narrow side straps for the purpose of fixing them to the edges of frames. They are of the butt type, and are used for shutters that have to fold back on the face of a wall. The projection of the knuckle must equal half the depth of the reveal of the opening into which the frame is sunk. The hinge is said to have obtained its name because it was introduced to comply with an Act of Parliament requiring that doors and shutters opening upon footways should be folded back upon the walls. They are made in sizes 4 in., 4½ in., 5 in. and 6 in., measured as shown in Fig. 7.

**The Pew Hinge**, Fig. *7a*, is a variation of the shutter hinge, having an egg-shaped joint, used, as its name implies, for pew and similar shaped doors.

**The Counter Flap Hinge**, Fig. 8, also known as a link hinge, when made in iron and of large size, for cellar flaps, is chiefly used for flaps in counter tops, the object of the link being to allow the flap to lie back flat on the counter without the necessity of having a projecting knuckle. As will be seen by the edge view, it is sunk flush with the top surface, and it is made of dovetailed shape to resist side pressure. Obtainable in cast-brass, gun-metal and nickelled steel. Sizes from 1¼ in. to 2½ in.

**Strap Hinges**.—This term is applied in the ironmongery trade to that class of hinge which fixes upon the face of the door, etc., and that is in two parts—that is, the axis or pivot upon which the hinge works is made, and is attached separately to the post or frame, and the band or strap, after securing to the door, is lifted upon the pivot. There are two distinct types—viz. single and double straps, and several varieties of each.

**The Hook and Eye Hinge,** Figs. 9 and 9*a*, is a common form of single strap hinge used for stable doors, etc., having to swing clear of obstacles at the bottom. It will reverse and the door can be readily lifted off the hook or pivot. Made in wrought-iron in sizes from 18 in. to 36 in., increasing 2 in. The one shown is drilled for bolts, but they can be obtained countersunk for screws.

**The "Park-Gate" or "Collinge" Hinge,** Figs. 10 and 11, is a typical double strap and spur hinge, used, as the name implies, for large entrance gates to gardens and parks. The hinge shown is the top one, and is for a right-hand-hung gate ; the lower hinge has no strap, merely a spur, and may work upon a centre pivot as at top, or, as is more usual, upon two pivots placed side by side about 3 in. apart to throw the gate up as it opens, to clear the rise in the roadway.

Collinge is the name of the inventor. The hinges are to be obtained from 2 ft. to 6 ft. long and to suit any thickness of gate.

**The Egg and Cup Hinge**, Figs. 12 and 13, is a single strap, and is used for coach-house and similar "close" doors. The strap is fitted with a ball or egg-shaped bearing, ground to fit a cup attached to the hanging plate. It is also provided with a cover or hood, which protects the bearings from dirt. Different shaped cup-holders are used upon wood, stone and brick piers. Fig. 13 shows the shape for a wood post and Fig. 14 for a stone pier. The one used in brickwork is forked, with the ends turned up and down.

**The Cross Garnet**, Fig. 15, known also as a **T**-hinge, is a common form of strap for light doors and gates. It is made in malleable and wrought-iron in sizes from 6 in. to 24 in. long. The form of joint shown in Fig. 15*a* is called a water joint.

**The Floor Spring Hinge**, Figs. 17 to 19, is, so far as its hinging property is concerned, merely a pivot hinge, but the lower pivot in this instance is connected to a shoe which carries the door, and to helical spring or springs (according to the make) contained in a metal box concealed in the floor. The object of the springs is to cause the door to close automatically. The shoe is usually arranged to swing both ways, and for that reason it is frequently called a swing-door hinge. The sizes vary with different makers, but the dimensions shown are average.

The top or visible plate is of brass, also the shoe, the remaining parts being of steel. As the doors must be fitted into the shoe, then into the opening exactly, the top pivot requires insertion after the door is in position.

The usual arrangement is shown in Fig. 18, where the plate *A* is fixed into the head of the door ; the plate *B* into the frame with the lever concealed in its thickness.

When the door is in position, the screw shown on the right hand is turned up, carrying the other end of the level down when the pin enters the socket and fixes the door. With thin or high doors it is necessary to have a hinge in the middle, to prevent their casting ; the usual form is shown in Fig. 19.

## CHAPTER X

## PRACTICAL GEOMETRY

Bevels and Angles in Oblique Planes. Simple Angles. Compound Angles—rotation of inclined plane. Cuts for Purlins against Hips. Oblique Cuts in Angle Braces—various positions of brace, development of inclined surfaces. Bevels in Splayed Linings—setting out the soffit. Properties of and methods of drawing Ellipses—definition of ellipse and terms connected with same. Sections of Cylinders. Describing Ellipse by intersecting lines, ditto by Trammelling. To find the Foci, Normal and Tangent of an Ellipse. False Ellipses. The Cone and its Properties—definitions, projections. The Conic Sections—how to produce them. The Covering of Cones. Development of Frustum of Cone. The Covering of Domes and Vaults—types of Domes. To obtain projection of boarding. To obtain Shape of boards laid vertically; ditto laid horizontally. A Gothic Dome—to project the ribs. An Elliptic Dome—to obtain the covering of. Setting out Arches in Brick and Stone—the gauged camber, round, elliptic, lancet, equilateral, Tudor, horseshoe, stilted, basket handle, ogee and squinch arches. Carpentry Arches—Gothic, method of finding centres for. The Wave, Ogee and Bell Arches. Complex Curves. The Helix—methods of drawing. " Pitch " explained. Development of Helical Curve. Projecting a Wreathed Handrail. The Spiral—definition. To draw the rising Spiral, the Plane Spiral. Drawing Scrolls

**The Determination of Bevels and Angles in Oblique Planes.**—This is a class of problem which in one form or another is constantly occurring in the workshop and drawing office. The carpenter meets with it in variety in framing up a roof; the joiner when fitting the mitres of splayed linings or joints of curved and splayed fascias, etc.; the bricklayer and the mason in preparing templets for splayed and skew arches or in the angles of window and door openings; the plumber when obtaining shapes of lacing sheets for turret roofs, etc. The reader who has followed the chapter on orthographic projection will scarcely need telling that a drawing of an angular or any other shaped plane surface gives the true size and shape of that surface only when projected upon a plane parallel with itself.

In most technical drawings in which oblique surfaces occur, however, these will be found projected upon a plane *not* parallel with the oblique surface, and to obtain either the real shape and dimensions or the true angles at the intersections special projections must be made, and it is with these we now deal. To make the matter quite clear as to when a special drawing or development is required, a few examples of intersecting surfaces at various angles which do *not* require special treatment are first given (see page 143).

**Simple Angles**.—Figs. 1 and 2 show two pieces of wood at right angles to each other, and it is obvious that the square applied as shown will give the correct cut for the joint. Again, in Figs. 3 and 4 we have the piece *B* fitted against the piece *A*, and as it lies horizontal in one direction its true shape is shown in the plan and a " square " gives the joint. The piece *B* is inclined in the other direction, consequently the view at right angles to the plan will show its true inclination, and the edge bevel is obtained as shown in Fig. 4. If piece *B* is level and piece *A* vertical, but making any angle with *B* in plan, then the true bevel is shown in the plan as at Fig. 6, and obviously the depth of the cut is square. Other simple angles are shown on page 146, on the left side of Figs. 1 and 2, and on Fig. 4.

**Compound Angles**.—These arise when one or both of the intersecting surfaces are at angles other than right angles—that is, square to each other—and one or both of the surfaces are inclined in transverse direction. Such cases occur in splayed linings or jambs, in hipped roofs, in angle braces, hoppers, etc., and the method of development now to be described will disclose the bevels or " cuts " required in all such cases.

Figs. 7, 8 and 9 show a horizontal board inclined at 30° across its width, fitting against a vertical board, standing at an angle of 45° in plan. The shoulder cut *a–b* is required. A glance at Figs. 7 and 9, the plan and eleva-

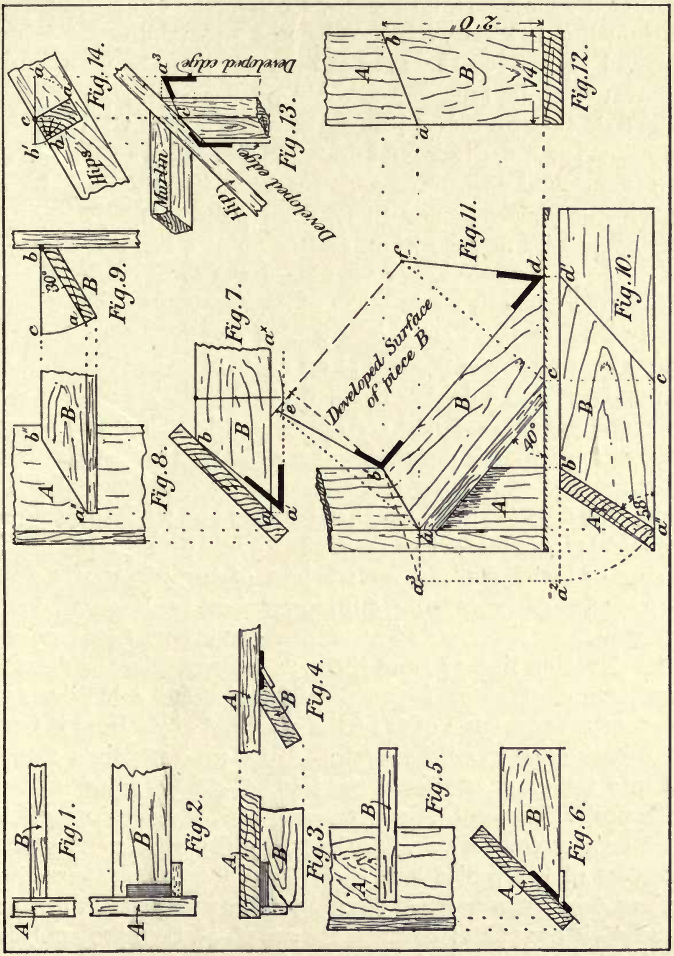


Fig.1.
A
B
Fig.2.
A
B
Fig.3.
A
B
Fig.4.
A
B
Fig.5.
A
B
Fig.6.
A
B
Fig.7.
Fig.8.
Fig.9.
30°
Fig.10.
58°
Fig.11.
40°
Developed Surface of piece B
Fig.12.
2'0"
14
Fig.13.
Murlin
Hip
Developed edge
Developed edge
Fig.14.
Hips
a
b
c
d
e
f

Practical Geometry—Bevels

Figs. 1 to 6. Simple Angles. Figs. 7 to 14. Compound Angles tion, which are the usual drawings given, will show that the true length of the line required, *a′–b*, is not shown in either drawing. If, however, we conceive the edge *a* lifted up until it is level with *b*, the point *b* remaining fixed, we should then have the surface parallel with the plan, and, drawn thus, its true shape would be disclosed.

To do this, set off on Fig. 7, the real width of the piece *B*, obtained at *a–b*, Fig. 9, and draw the developed edge parallel to its original position, $a$–$a^1$. Intersect this line at *a′* by a projector perpendicular to it, from point *a*; this locates point *a* in its new position, and as point *b* has not moved, if we join *a′–b*, obviously we obtain the true shape of the bevel or cut to fit against the piece *A*.

In Figs. 10 to 12 are shown a plan and two elevations of a vertical piece *A*, standing at an angle of 58° with the edge of its base, and a doubly inclined piece *B*, fitting against it; the oblique cuts *a–b* and *c–d* are required. To obtain these a similar method is pursued. It may be well to describe first the method of making the orthographic projections. The essential data are: the width of base is 14 in.; angle between vertical piece and edge of base, 58°; angle between base and brace or inclined piece, 40°; height of top of brace, 2 ft.; front edge of brace to be 5 in. lower than back edge. Proceed to draw Figs. 10 and 12 to these conditions, then project the elevation Fig. 11 from them, as indicated by the dotted projectors. Having found position of point *a* in Fig. 11, draw the front edge of *B* at the required angle from it and the back edge parallel thereto. Next project points *c* and *d* into the plan, and draw the joint *c″–d′*. This completes the projections and we can proceed with the developments.

The first thing required is the true width of piece *B*, which neither of the projections show. To obtain this, turn the piece *A* into the vertical plane by taking point *b″* as centre and *a″–b″* as radius; describe the arc $a''$–$a^2$, then project this point into the vertical plane as shown, and intersect it at $a^3$ by a horizontal projector from point *a*. Join $a^3$–$b'$, and the real length of the line *a–b′* is seen. Set off this length upon a perpendicular to the edge $b'$–$d$ drawn from $b'$. Draw a parallel to $b'$–$d$ through this point and the true width of $B$ will be obtained. Next we locate upon it points $e$ and $f$, by projecting perpendiculars from points $a$ and $c$. Join these points to $b'$ and $d$ respectively, and the true size and shape of the angle piece is obtained with the bevels as shown.

**To obtain the Cuts for Purlins against Hips**.—Figs. 13 and 14 are the plan and elevation of the angle of a hipped roof showing the ends of the purlins fitting against the hip rafter. These are the usual projections given, from which we obtain the bevels by developing the inclined surfaces of the purlin into a horizontal plane.

With point $c$ in Fig. 14 (the top edge of the purlin) as centre, and the widths of the edge and side as radii, describe arcs cutting the horizontal line in points $a'$ and $b'$. Drop projectors from these points into the plan and intersect them by perpendiculars from the edges of the purlin, where they come in contact with the hip, thus obtaining points $a^3$–$b^3$; join these to point $c'$ and the bevels are disclosed.

**Oblique Cuts in Angle Braces**.—Figs. 1 and 2, page 146, are the plan and elevation respectively of a post or standard resting upon a sole piece and counter braced. To utilise the space fully, different arrangements of the braces are shown on either side, but in practice they would be alike on each side. The brace on the left side, as will be seen by its plan, lies parallel to the plane it is drawn upon, therefore all its edges are shown in actual length and position and the bevels are obtainable directly from the drawing.

Upon the right-hand side the brace is shown with one of its diagonals vertical, or, stated otherwise, it lies with its arris edges in a vertical plane ; this can be better seen in the side elevation, Fig. 3. A bevel set to the projection would give the correct shape for the housing into the post, but not the bevel to apply to the sloping sides of the brace for marking the shoulder cuts. These must be obtained by developing the sloping surfaces or turning them into the vertical plane. Perhaps it would be clearer to say that the two edges must

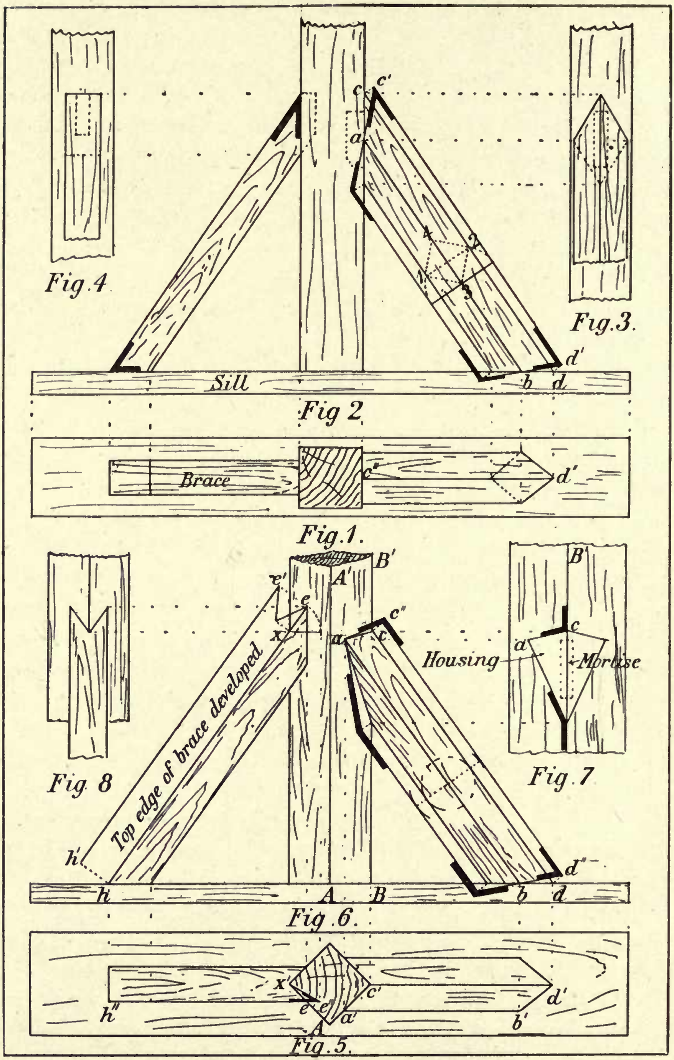


Fig.4.
c
c'
a
4
2
1
3
Fig.3.
d'
Sill
b
d
Fig 2
Brace
c'
d'
Fig.1.
B'
A'
e'
e
x
a
c
c''
Fig. 8
Top edge of brace developed
h'
h
A
B
d''
b
d
Fig.6.
B'
c
a
Housing
Mortise
Fig.7
x'
c'
e
e'
A
a'
d'
h''
b'
Fig.5.

Obtaining Bevels upon Oblique Planes

be brought into *one* plane ; it does not really matter which plane it is. As it may not be clear how the elevation of the brace is obtained, this will be first described.

Draw the line *a–b*, Fig. 2, at the pitch the brace is desired, and the line 1–2 perpendicular to this ; upon this set off the half-diagonal of the given brace on either side, obtaining the dimension from a drawing or the stuff itself. Draw parallels to *a–b* through 1–2, which will give the projections of the upper and lower edges.

The section of the brace is dotted-in to make the explanation clearer ; this is drawn by setting off the transverse diagonal and joining up the corners 1–2–3–4. Next draw a line square to the pitch through the lower corner and turn the sides down upon it. Draw parallels to the edges through these points and intersect them by perpendiculars drawn from each end of the brace as at *c–d*. Join the points so obtained to points *a* and *b*, and the bevels will be found.

A similar post is shown in Figs. 5 and 6. Here the post is so placed that the braces pitch against its diagonal.

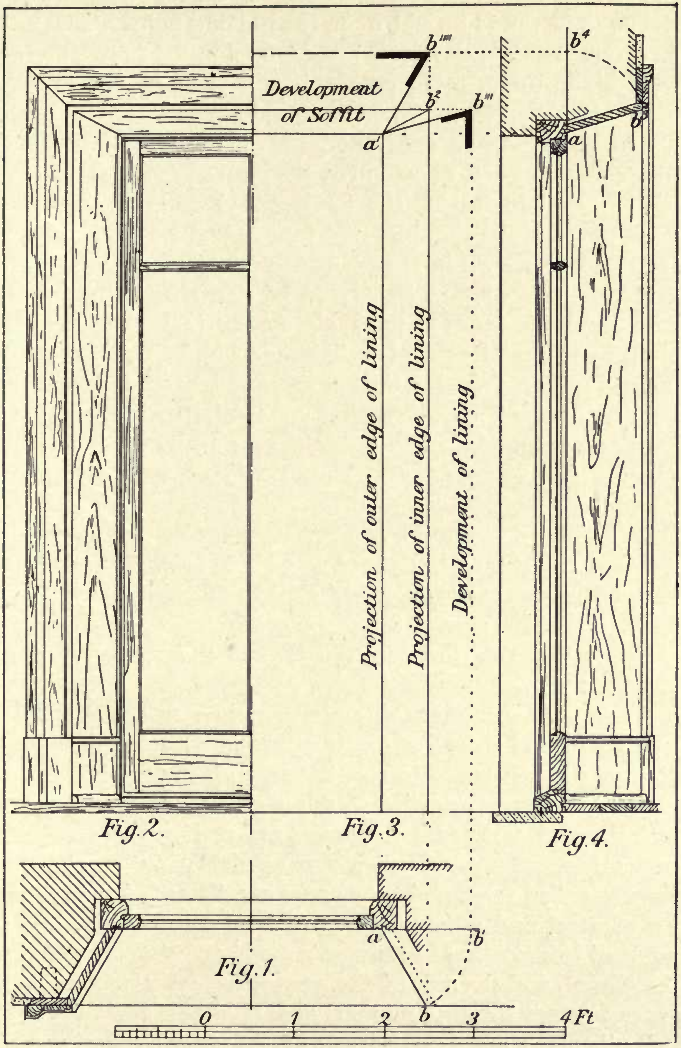
The same method is used to obtain the bevels for the right-hand brace, which should offer no difficulty to the student, although the bevels obtained differ from the last set. The braces being square in section, both cuts are really alike, and the development of the undersides is unnecessary, but both are shown to make the method clear.

If the brace were at an angle of 45° only one bevel would be necessary, as each end would be alike. On the left side of Fig. 5 the brace is shown with its sides parallel to the vertical plane, consequently the down cut and foot cut are shown correctly in the elevation. Two methods of obtaining the edge cut or bird's-mouth are shown. First the point *e* may be thrown down level with *x*, the lowest point in the bird's-mouth, and projected into the plan, where it is intersected at $e''$ by the side $h''$ produced. Join $e''$–$x'$ and the true shape of the bird's-mouth is seen. Second, a development of upper side of brace may be made on the elevation, projecting across it the point *x* to the middle, where it meets the angle of the post. Join this point to *e–e′* and a templet for marking the brace is obtained.

In Fig. 7 a development of the two adjacent sides of the post is made, chiefly to show the limits within which the mortise and tenon must be made; also how to mark the housing. The bevels are the same as those found for the brace, but are applied in reverse direction. The distance of point *a* from *c* is found in the plan; the heights of the points are projected from Fig. 5.

**Obtaining the Bevels of Splayed Linings.**—An opening fitted with a French casement frame, having splayed linings to jambs and soffit, is shown on page 149. One-half of plan and elevation is shown in detail, the other half in line diagram, showing the developments necessary to determine the true angles at the mitre, to obtain the bevels for marking the shoulders. The soffit is splayed at a less angle than the jambs, the usual method, as the splay is given only for effect, it is not necessary to obtain light; the rays of light pass downwards not upwards, and the ceiling is lighted by reflection from the surfaces in the room. If the splays were alike, only one bevel would be required. The mitre line $a'$–$b^2$, shown at top of Fig. 3, is the projection of the angle, and is not its real length or inclination. To obtain this we must turn the lining round parallel to the front. Let *a*, Fig. 1, be the pivot, move *b*, the outer edge of the lining, round to $b'$; the edges represented by *a* and *b* will then be in one plane. Referring to the elevation, point $a'$ will not have moved in the operation, point $b^2$ has moved out horizontally to $b'''$, which is the point where the two projectors meet. Join this point to $a'$ and we have the shoulder line for the jamb. To obtain the bevel for the soffit. In like manner upon section Fig. 4, with *a* as centre and $a$–$b^3$ as radius, describe an arc intersecting the vertical plane in $b^4$. Project this point into the elevation, cutting the projector from the face of the jamb in b″″.

Join this point to $a'$ and the bevel for the head groove is disclosed.


b''''
Development of Soffit
b²
b'''
a'
b⁴
a
b³
Projection of outer edge of lining
Projection of inner edge of lining
Development of lining
Fig. 2.
Fig. 3.
Fig. 4.
a
b'
Fig. 1.
b
0
1
2
3
4 Ft

Obtaining Bevels in Splayed Linings

Fig. 1. Plan of French Casement Window. Fig. 2. Half Elevation of Same. Fig. 3. Development of Linings. Fig. 4. Vertical Section of Window

The soffit would be laid upon the rod and point *a′* marked on each side, then the bevel just found applied to front edge with blade intersecting point *a′*, and the line cut in. A second line about ⅜ in. farther out and parallel with the first, would be added to mark the groove for the reception of the tongue which is cut upon end of the jamb.

The bevel found for the jamb would be applied at the back to mark the shoulder, the tongue being formed on the face side, as shown in the plan.

**Properties of and Methods of drawing Ellipses.**—The ellipse is a figure used almost as frequently as the circle by the architectural draughtsman, and its construction is constantly required in the workshop. There is a considerable amount of misconception concerning this figure; it is often confounded with other figures to which it has no relation, for instance the oval and the three-centred circular curve.

**Definitions.**—The Ellipse is a section of either a cone or a cylinder. It may be defined as a plane figure bounded by one continuous curve described about two points (called the foci), so that the sum of the distances from any point in the curve to the two foci may be always the same (see Fig. 7, page 152).

**Axes.**—A diameter of an ellipse is any straight line cutting it in halves by passing through its centre. One diameter is conjugate to another when it is parallel to the tangents passing through the ends of the other. The longest and shortest conjugate diameters are at right angles with each other, and as the figure is symmetrical about them, they may be called axes, and they are generally called the major (or greater) and minor (or lesser) axes respectively. The point of intersection of the two axes is called the centre of the ellipse, and the axis of the generating cylinder (or cone) always passes through this point.

**Ordinates** are lines drawn from the circumference perpendicular to the axis or diameter (see Figs. 1 and 2).

**Foci.**—Two points on the major axis, from which the curve has a constant ratio—that is, the sum of the distance of any point in the curve from the two focal points is equal to the length of the major axis ; this will be demonstrated in reference to Fig. 7.

**Normals** are lines perpendicular to the curve at any particular point.

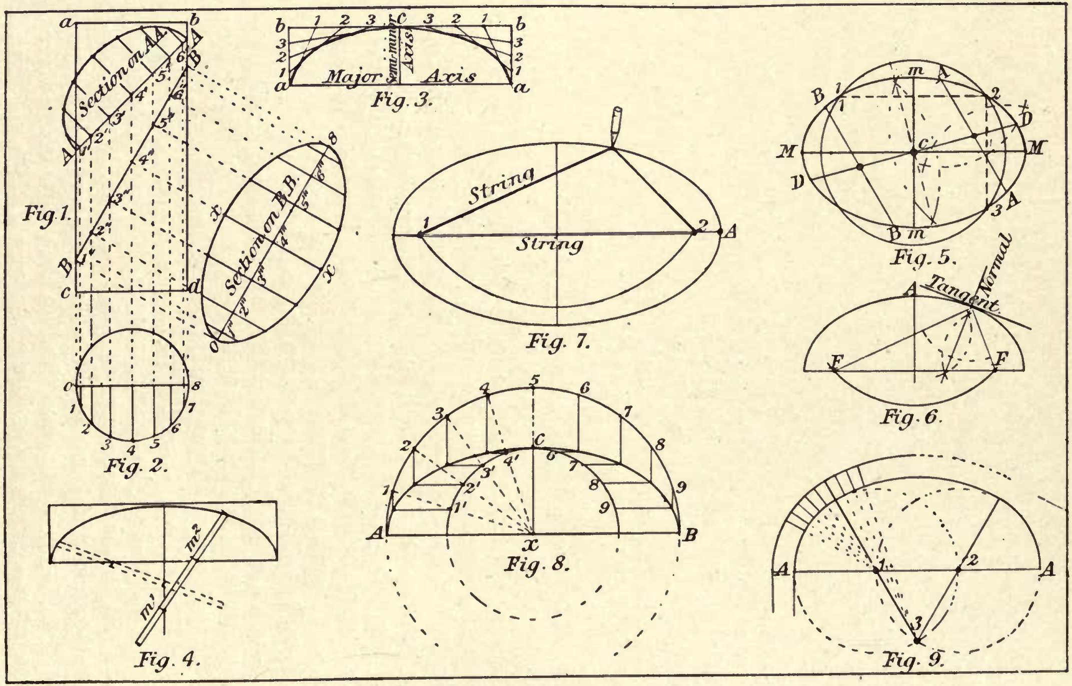
**Tangents** are lines at right angles to the normal and touching the curve.

**Trammel.**—An apparatus or instrument for describing elliptic curves mechanically.

**Trammelling.**—A method of plotting an ellipse upon its axes similar in principle to the action of the trammel.

**Methods of drawing the Ellipse.**—There are many methods of doing this, several of which are shown on page 152. First as the section of a cylinder. Let *a–b–c–d*, Fig. 1, be the elevation of a cylinder, whose plan is shown in Fig. 2. To obtain the section made by a plane on the line *A–A*, divide the semi-circumference of the plan into a number of equal parts, as 1, 2, 3, 4, 5, 6, 7, 8 ; project these points to the line of section as shown by the dotted projectors, numbering them similarly for easy reference. Erect perpendiculars to the line of section from these points, and make them equal in length to the corresponding ordinates in plan. Draw the curve through the points so found. Another plane of section is shown by the line *B–B*, and the complete section is described on a line parallel to the line of section, but clear of the generating solid. The same projectors are utilised as in the first case, the only difference in treatment being that the lengths of the ordinates are set off on each side of the central line or major axis, 0–8.

**To Describe a Semi-Ellipse** by means of intersecting lines, Fig. 3.—Draw a rectangle upon the major axis equal in height to the minor axis, as *a–b*, *b–a*. Divide each side into the same number of equal parts as shown ; join points *a*–1, 1–2, 2–3, 3–*c*, etc., and through the points where these lines intersect each other, draw the curve. If a sufficient number of divisions are used the curve will be described by


Section on A.A.
Section on B.B.
Fig. 1.
Fig. 2.
Major Axis
Semi-minor Axis
Fig. 3.
Fig. 4.
Fig. 5.
Tangent
Normal
Fig. 6.
String
String
Fig. 7.
Fig. 8.
Fig. 9.

Methods of drawing Ellipses

the intersecting lines, all of which are tangents, and each one produces a point in the curve.

**To Describe the Ellipse by Trammelling**, Fig. 4.—Draw the major and minor axes perpendicular to each other. Take a strip of paper or wood and mark off from one end the lengths of the semi-major and semi-minor axes respectively, as shown at $M^1$, $M^2$. If now the strip is placed across the axes so that these points rest on them as shown in two positions in Fig. 4, the end of the rod will be in the curve at that particular point, and if it is marked with a pencil a sufficient number of such points may be found, through which the curve may be drawn either freehand or by aid of wood curves. This method is especially useful in producing small ellipses in which the trammel itself is rather cumbersome.

Another method of drawing an ellipse by means of intersecting lines is shown in Fig. 8, and it is, perhaps, the clearest and best for draughtsmen. Draw the major axis *A–B*, and the semi-minor axis *x–c* perpendicular to it. Describe two circles, one on the major axis, the other on the minor (one-half only is shown). Divide each semicircle into the same number of equal parts, and this is best done by drawing radials from the centre to the divisions on the large circle; these will divide the smaller one similarly, as shown by the dotted lines in the left quadrant. From the points on the outer circle draw ordinates parallel with the minor axis, and from the corresponding points on the inner circle draw lines parallel to the major axis. The intersections of these lines will be points in the elliptic curve, which may then be drawn through them.

**To find the Centre and Axes of a given Ellipse.**—Let *M–M*, *m–m*, Fig. 5, be the given ellipse; draw any two lines parallel and cutting opposite sides of the ellipse, as *A–A* and *B–B*. Bisect each of these and draw the line *D–D* through their centres. Bisect *D–D* in point *C*, which is the centre of the ellipse. To determine the direction of the axes. With *C* as centre, and any radius, describe a circle cutting the ellipse in points 1–2–3. Join 1–2 and 2–3, and lines drawn parallel to these through the centre will be the major and minor axis respectively.

To find the foci, normal and tangent, of any ellipse (see Fig. 6). With the semi-major axis as radius and either end of the minor axis as centre, describe an arc cutting the major axis in *F.F.* These are the two focal points.

**Normals.**—Let *n*, Fig. 6, be a point in the curve to which we desire to find a normal or perpendicular. From this point draw lines to the foci *F–F.*, and bisect the angle contained between them. This is done by describing an arc from point *n*, and from the ends of the arc, with same radius, describe intersecting arcs. Draw a line through this point and the given point *n*. This line is normal to the curve at that particular point, and any other may be found in like manner. This method is used to obtain the joint lines of the voussoirs in elliptic arches, and for the ribs of centering.

A **tangent** at the same point is readily found by drawing a line at right angles to the normal and touching the curve.

**To describe an Ellipse by Means of a Looped String,** Fig. 7.—Draw the conjugate axes to dimensions required, and find the focal points as described in Fig. 6. Drive two pins in the foci, as at 1–2, and a third pin at *A*, one end of the major axis. Form a tight loop with thread or string around the two pins at 1 and *A* ; having fastened the loop, remove the pin at *A* and substitute a pencil. The loop will now lie around the two pins 1–2, and a regular and continuous curve will be produced by keeping the string tant and moving the pencil around from point *A*, as shown (the original of this drawing was actually produced by the method described). In practice, with large curves, a difficulty is experienced in preventing the string stretching, and so interrupting the continuity of the curve, hence trammelling is more often resorted to in the workshop. For draughtsmen's work a silk thread is often employed.

**The False or Three-Centred "Ellipse,"** Fig. 9.—This figure is drawn with compasses, and is therefore not a true elliptic figure, but is an approximation thereto, much used by bricklayers for setting out templets for what they describe as "elliptic" arches.

Draw the span or major axis *A–A*. Divide this into three equal parts, in points 1–2. With these points as centres, and 2–*A* as radius, describe circles intersecting in point 3. Draw lines from the intersection through points 1 and 2 to cut the circles, and these give the radius for describing the central part of the curve, the two ends being formed by segments of the circles already drawn. It will be seen that only two shapes are required for the bricks in this arch.

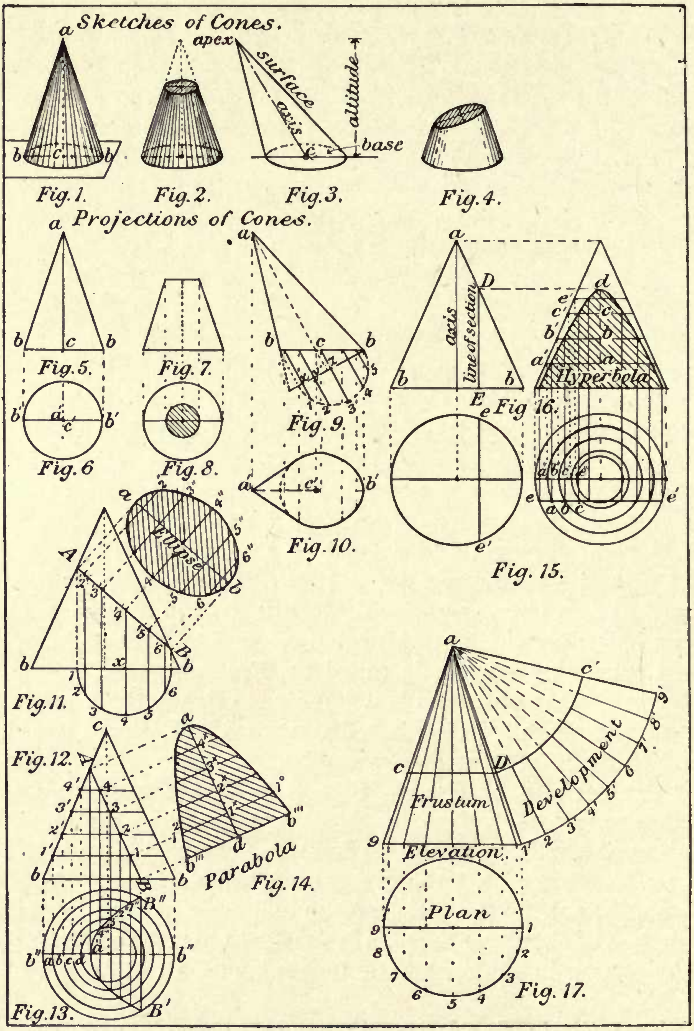
## THE CONE AND ITS PROPERTIES

**Definitions.**—There are two kinds of cones—right and oblique. A right cone has its axis perpendicular to its base; an oblique cone has its axis at some other angle than a right angle with its base (see sketches, Figs. 1 and 3, page 156). The axis of a solid is a straight line drawn, or imagined, connecting the centres of its opposite ends.

A right cone may be defined as a solid with a circular base, and sides tapering to a point. It may also be described as a circular pyramid. When the top portion of a cone (or other similar solid) is cut off parallel with its base, the remaining portion is called the Frustum (see Fig. 2). When the line of section is oblique, as in Fig. 4, the portion remaining is called Ungula, a Latin word signifying a hoof, which the solid somewhat resembles.

**Projections of Cones,** Figs. 5 to 8, are respectively elevations (or sections, as they are exactly alike) and plans of a right cone and its frustum; the projectors indicate how the plan is obtained from the elevation. Figs. 9 and 10 are the projections of an oblique cone, and as the method of obtaining the plan is similar to that for obtaining the section in the next case, its explanation will be dealt with there.

**The Conic Sections** are five in number, named respectively the triangle, see Fig. 5, a section through the


Sketches of Cones.
a
b
c
b
apex
surface
axis
altitude
base
c
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Projections of Cones.
a
b
c
b
Fig. 5.
b′
a
c
b′
Fig. 6
Fig. 7.
Fig. 8.
a
b
c
b
Fig. 9.
a
c′
b′
Fig. 10.
a
D
axis
line of section
b
b
E
e
Fig. 15.
e′
d
e′
c′
b′
a′
Hyperbola
Fig 16.
a b c d e
e
e′
a b c
Fig. 15.
a
Ellipse
A
B
b
b
x
Fig. 11.
Fig. 12.
Fig. 13.
c
A
4′
3′
2′
1′
b
b
B
B″
b″
a b c d
a
b″
B′
a
d
b‴
b‴
Parabola
Fig. 14.
a
c′
c
D
Frustum
Development
9′
9
Elevation
1′
Plan
9
1
8
2
7
3
6
5
4
Fig. 17.

The Conic Sections and Coverings of Cones axis and diameter of its base; the circle (see Fig. 6), a section at right angles to the axis; the ellipse (see Fig. 11*a*), a section through the two inclined sides at an oblique angle to the axis; the parabola (see Fig. 14), a section through one side and the base, parallel with the other side; and the hyperbola, Fig. 16, a section made by a plane passing through the base and side of the cone, and making a greater angle with the base than the side of the cone makes.

It is not possible to cut a cone in any other direction than the above named, and, though the sizes of the sections will vary according to their positions on the cone, their shapes will be constant. It may be noted that all the five figures can be obtained by other methods than as sections of cones, but no other solid contains them all, hence the generic term of conic sections. Some geometricians hold that there are only three conic sections, because the triangle and circle are common to other solids, and they define these as particular cases of the parabola and the ellipse respectively.

**The Ellipse**, Fig. 11.—To obtain this section, draw the elevation of the cone (and it may be here interpolated that it will be advisable for the student to draw these figures at least four times the size shown, and to take more points than are shown on the drawing, where they are limited to avoid a confusion of lines) and the line of section as *A–B*; project the extremities to the base *b–b*, and describe a semicircle cutting the points as shown. Divide the semicircle into any number of equal parts as 1, 2, 3, 4, 5, 6, and project these upwards to cut the line of section, then project ordinates from these points, at right angles to the section lines. Draw a line *a–b* across them, parallel with the line of section (this is merely done for convenience, the section could be drawn upon the line of section if desired). Make each of these ordinates equal in length, on each side of the line *a–b*, to the corresponding ordinate in the semicircle, which is a plan of the section, and draw the outline of the section through the points so found. The more points used the truer will be the figure. It will be noticed that the semicircle might equally well represent the half plan of a cylinder whose sides are cut by the line *A–B*, and obviously the same section would be obtained.

**The Parabola**, Fig. 14.—To produce this, draw the desired line of section *A–B*, Fig. 12, and divide it into a number of equal parts, as 1, 2, 3, 4. Through these points draw lines parallel with the base, and cutting the sides of the cone in points 1′, 2′, 3′, 4′. These lines may be taken to represent a series of horizontal sections of the cone, and their planes will becircles. To determine their size, drop projectors—dotted —into the plan, cutting the diameter in *a*, *b*, *c*, *d*; from the middle of the diameter as centre and these points as radii, describe concentric circles. Next drop projectors—full lines—from points 1, 2, 3, 4, and the extremities in the line of section *A–B*, into the plan, cutting the appropriate circles in points *B*″, 1″, 2″, 3″, 4″, *a*′, and draw a curved line through these points on each side of the diameter as shown; draw also the plan of the base of plane of section *B*′–*B*″, thus obtaining the shape of the section in *plan*. To obtain its real shape, draw the line *a–d* parallel with *A–B*, and project ordinates across it, from the points in section line. Make these equal in length on each side of *a–d*, to the similar numbered ordinates in the plan, measured from the diameter *b*′–*b*″, and draw the curve through the points so found.

**The Hyperbola** (see Fig. 16).—Two plans and elevations are given, the first pair to show the position of the line of section *E–D* in elevation, and *e–e*′ in plan. Obviously we are looking at the edge of the section, therefore cannot see its shape. To obtain this the plan must be revolved on its centre until the line of section is parallel to the vertical plane. This is shown in the right-hand plan, and a new elevation is projected from it. Divide the diameter into a number of equal parts, and from the centre describe circles through them as at *a*″, *b*″, *c*″, *e*″; project these points into the elevation, cutting the side of the cone in *a*′, *b*′, *c*′, *e*′, and draw lines through them parallel to the base: these lines are, of course, the edges of sections of the cone, of which the circles in Fig. 15 are the respective plans. Next, from points *a*, *b*, *c*, *h*, where the circles are cut by the line of section, raise perpendiculars to intersect the horizontals in elevation, and draw the curve through these intersections as shown.

**To obtain the Covering of a Cone.**—Let Fig. 17 represent the plan and the elevation of a right cone. If we divide one-half the circumference of base into a number of equal parts, as points 1 to 9, and project these to the base line in elevation, then draw straight lines from the points to the apex of the cone *a*, we shall have the elevations of a series of lines drawn at equal distances apart upon the surface of the cone, and by their aid we can locate a point or number of points on that surface.

**To obtain the Development of the Semi-Cone** (*a*–1′–9).—With point *a* as centre and *a*–1′ (the length of side) as radius, describe an arc. Upon this set out an equal number of spaces as shown in the plan; and from the last, point 9′, draw a line to *a*.

Then the space bounded by the lines *a*–1′, 9′–*a* will exactly cover half the cone, and if the other half is completed similarly, the whole surface will be obtained.

**To obtain the Development of Frustum of a Cone** as shown by the elevation, *C*–*D*, 1′–9, proceed as described to obtain the covering of the entire cone, and from the apex *a* describe an arc from *D*, the top of the frustum. The portion enclosed between the two arcs, and the sides *D*–1 and *C*′–9′, is the covering of one-half of the frustum.

If the whole cone is not given, all that is necessary to locate point *a* is to produce the sides of the frustum until they meet. In a subsequent example (page 189) a further use for the radial lines is shown.

**The Coverings of Domes.**—A dome is a vaulted roof having a circular, elliptic or polygonal plan. The first kind are termed spherical domes or vaults; the second, ellipsoidal domes; the third are specified by terms indicating the number of sides to the plan, as square, pentagonal, hexagonal, octagonal, etc., domes. There are also sub-varieties due to differences in the elevation or vertical sections, such as ogee domes, gothic or pointed domes, segmental, etc.

The construction of the dome, depending so greatly upon its size and circumstances of location, can only be referred to incidentally, the subject of this section being the method of obtaining the true shapes of the coverings, which is common to all.

A dome may be covered either by boards or metal sheets in vertical strips called "gores," or horizontal bands called "zones." Both methods are shown in the case of the spherical dome, Figs. 1 and 2, page 161. We will consider the vertical method first.

Fig. 1, *B* and *C*, show respectively quarter plans of the outside and inside of the dome, Fig. 2 being the interior and exterior elevations. The radial lines in quadrant *B* are the plans of the joints of the boards, and the elliptic lines in Fig. 2 their elevation. Neither set of lines gives either the true length or the shape of the edge, but both are necessary to obtain the true shape.

**To obtain the Projection of the Boarding.**—Divide the circumference of the plan into as many segments as the width of the boards to be used permits. Draw lines from these divisions to the centre. Next divide the circumference in the elevation, Fig. 2, into a number of equal parts as 1, 2, 3, 4. Draw indefinite horizontal projectors from these points, also vertical projectors into the plan, cutting the diameter in points 1, 2, 3, 4. With these points as radii, describe arcs from the centre of the plan, and projectors taken up from their intersections, with the various joint lines, to the corresponding horizontals, will give points in the elliptic curves forming the edges of the boards. Only one set of these projectors has been taken up, sufficient, however, to indicate the method; these are distinguished by chain lines, the points found are marked I., II., III., IV.

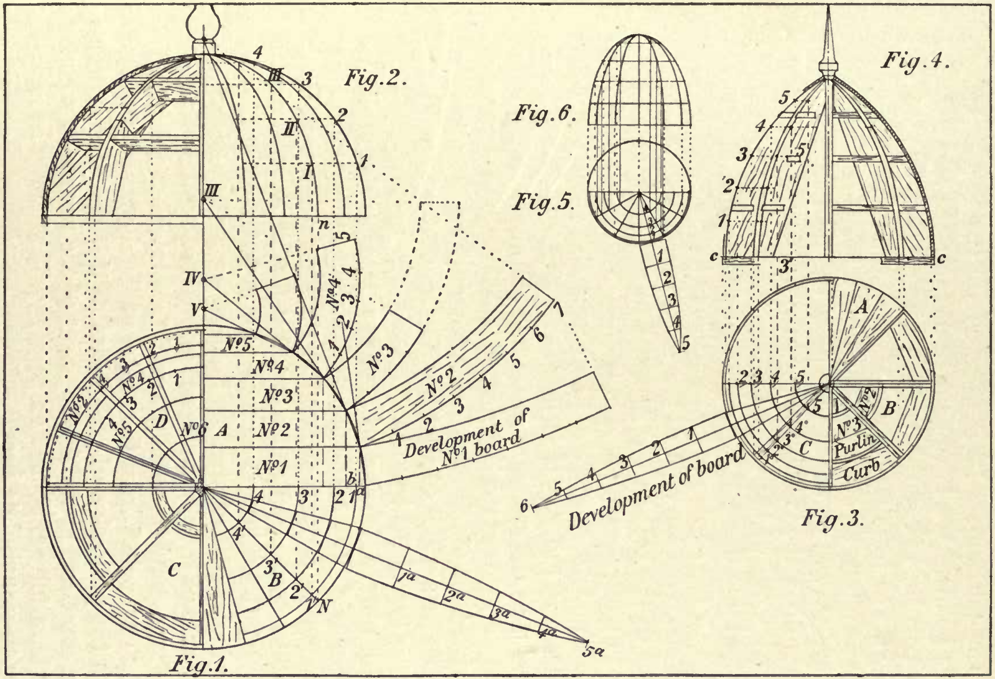


Fig.1.
Fig.2.
Fig.3.
Fig.4.
Fig.5.
Fig.6.
Development of
Nº1 board
Development of board
Nº1
Nº2
Nº3
Nº4
Nº5
Nº6
A
B
C
D
N
n
b
Purlin
Curb
III
IV
V
I
II
1a
2a
3a
4a
5a
c

The Coverings of Domes

Figs. 1 and 2. Plan and Elevation of a Spherical Dome, with Developments of Coverings. Figs. 3 and 4. Plan and Elevation of a Gothic Dome. Figs. 5 and 6. Plan and Elevation of an Elliptic Dome

Taking the joint at *N*, the projectors are shown starting from points 1′, 2′, 3′, 4′, and locate points *n*, *I*, *II*, *III*, *IV* on the horizontals in Fig. 2. Draw the curve through these points. We have next to discover the *true* shape of the board. Bisect the width of any board in plan and draw a line from the centre through the point, extending it indefinitely as shown. Mark off upon this line points $1^a$, $2^a$, $3^a$, $4^a$, $5^a$, equal in length to the like numbered points upon the circumference in elevation—that is, make a stretch-out of the curved line. Draw perpendiculars to the mid line through these points and make them equal in width to the corresponding portions of the respective arcs, passing across the plan of the same board—*i.e.* $1^a$ is made equal to the stretch out of arc 1 in the plan, and so on. In the scale drawing it is near enough to make each ordinate equal to a straight line across the plan, but when setting out full size it is necessary either to develop the segment of the arc or to make due allowance in the width for the curving of the board when nailed down to the purlins. Having thus obtained a series of points on the ordinates, draw the curved edges through them. One mould will answer for all the boards.

**To obtain Shape of Boards laid horizontally** as shown at *A*, Fig. 1, which may be taken to represent a half elevation of a dome covered in six zones.—As the boards have to be marked and cut whilst flat, it is necessary to convert the spherical surface into a series of planes, by drawing chords of straight lines between the ends of the segments of the circumference intersected by the joints.

If we extend these chords until they intersect a perpendicular or " pole " from the centre of the dome, we can deal with the projection of each board as if it were the section of a cone, and as the development of the surface of a cone has been fully explained on page 159, it will only be necessary to recapitulate here.

Take No. 2 board as example. Produce its chord line to meet the centre line in point *II*. This becomes the apex of its cone. From this point as centre, and the upper and lower edges of the board as radii, describe arcs indefinitely. Next project the ends of the chord to the base as at *a–b*; these projectors are shown in chain line. From the centre, with the points *a–b* as radii, describe arcs, which will represent the lower edges of the boards, Nos. 2 and 3, in plan. Note, to avoid confusion with the previous boarding, these plan lines are drawn in the quarter plan *D*, and numbered 2 and 3 respectively. These lines represent also the base and frustum of the cone we are to develop, and we divide the quadrant into a number of equal parts, stepping off the same number on the lower edge of the development of board No. 2. Join the last point, No. 7, to the apex and the length and shape of the board is determined. Of course the actual length of the board will depend upon the situation of the ribs, also the width of stuff available from which the curved segment is to be cut. The other boards are found in a similar manner, each board having its special "cone." The respective apices are numbered *III, IV, V*. The lowest board, No. 1, has its apex beyond the edge of the page, and would be set out in full size by the three-point method of drawing an arc. It will be noticed that with the vertical method of boarding it is necessary to use purlins, and these are made to lie perpendicular to the curve. Two of these purlins are shown in the quarter plan *C*. When horizontal method of boarding is adopted, the ribs must be placed much closer together, consequently thinner stuff may be used than with the vertical method. The dome shown is supposed to be about 8 feet in diameter. As the interiors of these small domes are not seen, it is usual to leave the inner edges of the ribs straight; the purlins are shaped to reduce the weight.

**A Gothic or Pointed Dome** is shown in Figs. 3 and 4. These are usually boarded vertically, and the ribs are all of the same shape, the radius of the arc being equal to the span. The purlins are in such case placed horizontally, and are of just sufficient thickness to take the nails without splitting, their width affording all the strength required. They need not equal the ribs in depth, and the housing to receive their ends should be stopped, as shown in the elevation of second rib, to afford an abutment.

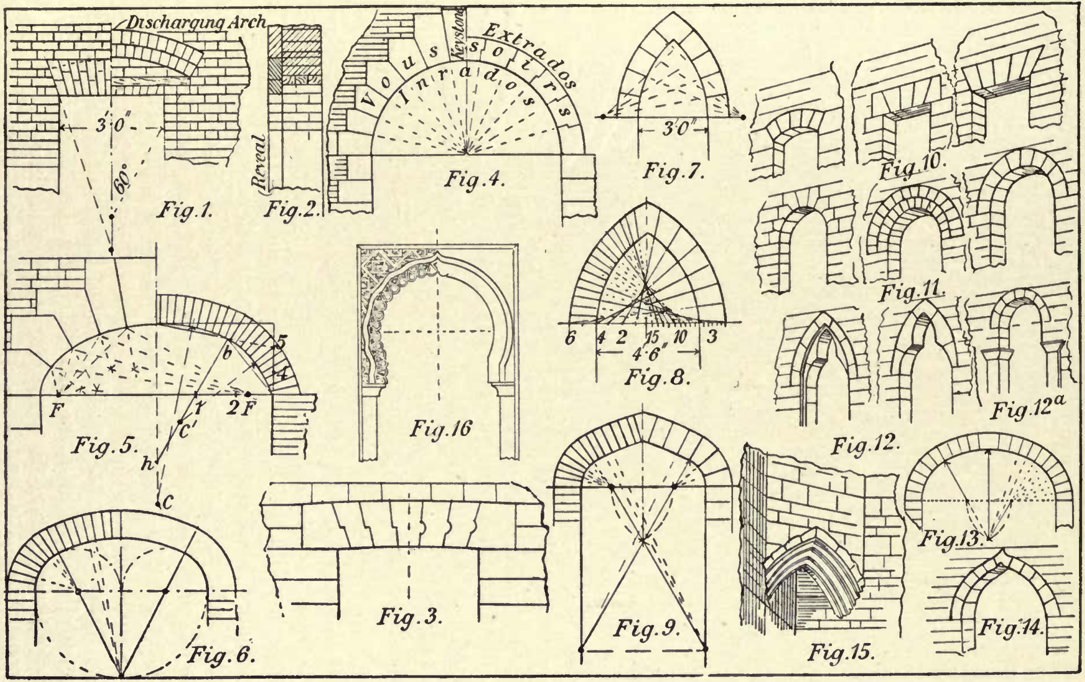
The plan, Fig. 3, shows at *A*, plan of the boarding, at *B* plan of purlins and curb, at *C* the geometrical construction for projection of ribs and shape of the boarding.

**To project the Ribs in Elevation.**—Having first described the outline of roof, by arcs struck from points *C* and *C*, divide the curve of one side into a number of parts, and drop projectors into the plan, cutting the diameter in points 1, 2, 3, 4, 5, 6. Carry round these points to the face of the rib to be projected, by circles struck from the centre. These new points are marked 1°, 2°, 3°, 4°, 5°. Project them upwards to cut horizontals drawn from the original points in the elevation, and draw the curve through the intersections. The development of the boards is obtained as explained for a spherical dome.

**An Elliptic Dome** is shown in Figs. 5 and 6. The solid on which this is based is termed an ellipsoid, the geometrical definition of which is a solid produced by the revolution of an ellipse upon its axis. Obviously, any section of the solid passing through the generating axis will be an ellipse, and, as when anything revolves, its path must be a circle, any section perpendicular to the axis—*i.e.* parallel with the transverse axis—will be a circle. We know from this that in an elliptic dome with its ribs arranged as shown in the plan, Fig. 5, all the ribs will be of the same contour, and that the covering boards must also be all alike. The procedure to obtain the projections and development of the covering is precisely as in the last case.

## THE DRAWING OF ARCHES—BRICK AND STONE (page 165)

**The Gauged or Flat Arch**, Fig. 1, is employed only in comparatively narrow openings, and, though generally drawn straight upon the soffit or underside, is really slightly


Discharging Arch
3'0"
60°
Fig.1.
Reveal
Fig.2.
Voussoirs
Keystone
Extrados
Intrados
Fig.4.
3'0"
Fig.7.
Fig.10.
Fig.11.
Fig.12.
Fig.12^a
F
1
2F
b
5
4
c'
h
c
Fig.5.
Fig.16
6
4
2
15
10
3
4'6"
Fig.8.
Fig.6.
Fig.3.
Fig.9.
Fig.15.
Fig.13.
Fig.14.

Brick and Masonry Arches

cambered or curved upwards in practice, when made in brickwork. The term "gauged" is applied to these because the bricks are cut to a gauge or templet, to ensure them being the right size and shape in each course. The method of setting-out to be described is that pursued to obtain the templets. Draw a centre line and set off the width of opening on each side. Draw the soffit line perpendicular to the centre line, and measure upwards as many courses as the arch is to be deep, which in the example is four. The exact height will vary with the character of the work and must be measured directly therefrom. Having found this, draw the back or extrados line horizontal—that is, parallel with the soffit line already drawn. Set up on the centre line, the camber, which should be $\frac{1}{8}$ in. for each foot of span, and either bend a lath around to the three points and mark the curve by its aid, or use the turning-piece for the purpose. Next determine the angle of skewback which locates the common centre of the arch. There are various methods and ratios adopted for this. A common one is to make $\frac{1}{8}$ in. the depth of arch, the amount that the back is longer than the soffit on each side; another, to add $1\frac{1}{2}$ in. for each foot in span. This latter method is shown in the example. Produce the line of skewback to meet the centre line, and all the joints are drawn to the intersection. From this centre, with radius equal the height to the crown, describe an arc, and upon this set out the voussoirs equally, starting with the key, which should be spaced equally on each side the centre line; draw the bed joints horizontal, and all the lines are then obtained for marking the templets. The hidden discharging arch at the back, which carries the load, is, of course, not set out on the rod, the necessary "pitch" being given to bricks in the jointing, when laying them over the core or bed, but in making the drawing on paper, start the skewback just clear of the end of the wood lintel, which is usually tailed into the wall the depth of half a brick, and pitch it 60° to find the centre for striking the curves.

**The Mason's Flat or Camber Arch,** Fig. 3, shows two methods of jointing: stepped joints on the left and joggle joints on the right. All the joints radiate from a common centre, which is not the centre of the camber, but is placed according to taste. The " skewback " is horizontal, as there is no spreading thrust on this arch.

**The Round, Roman or Semicircular Arch,** as it is variously termed, Fig. 4, shows two methods of treatment in stone arches. The stepped or rebated voussoirs on the right, with curved extrados, are used when all the structure is in stone and appearance is of less importance than strength. The step extrados arch shown on the left is chiefly used in conjunction with brickwork, the back joints of the arch falling on the course joints of the brickwork, the perpend being a multiple of 3 in.

**The Elliptic Arch,** Fig. 5, is shown in stone on the left side and bricks on the right. In the first, which is a true ellipse drawn as described on page 153, the voussoirs are worked out to a level seating with bed joints normal or perpendicular to the curve, at the points they occur. The setting out is shown, and is described on page 154. The right half shows the four centred or " bricklayers' ellipse," which, being composed of segments of circles, is not an ellipse at all, as no part of a true elliptic curve can be struck with compasses; but it is a convenient arrangement, as only two templets are required for the voussoirs, whilst in a true ellipse a separate templet is required for each voussoir. To draw this arch, construct a rectangle on the springing line and rise; divide the half span and the rise each into three equal parts, as at 1, 2, 4, 5. Set off on the centre line point *h* at a distance below the springing equal to the rise above it. Draw a line from *h*, through point 1, until it intersects a line drawn from point 5 to the crown in point *b*; then draw chord lines from *b* to the spring and crown; bisect these two lines and produce the bisectors until they cut the centre line and the line *h*–*b* in points *c* and *c'*. These points are the centres of the curves and the bed joints of the voussoirs are drawn to them.

**The False Ellipse,** Fig. 6, is another method of describing an approximation to an ellipse which has been fully described on page 155.

Pointed arches are typical of the so-called Gothic styles of architecture, and they are always formed by combinations of segments of circles. The simplest and earliest form is the

**Lancet Arch**, Fig. 7. This is always described with radii greater than the span, but varying according to requirements. In the example they equal one and a half times the span. The bed joints are drawn to the centre from which the segment is struck.

**The Equilateral Arch**, Fig. 8, has its radii equal to the span, the centres being at the opposite springings. The bed joints are sometimes made to radiate from the centres, but a better appearance is obtained by dividing up the soffit and springing equally in the following manner. Ascertain how many voussoirs are required on either side ; then divide the springing line between the centre of the opening and the extremity of the extrados into as many equal parts as there are to be voussoirs, not counting the keystone. In the example, six are taken for the stone arch and fifteen for the brick arch. Divide the soffit between springing and keystone into the same number of parts and join the points as shown, producing the lines across the face of the arch to obtain the bed joints.

**The Tudor or Four-Centred Arch,** Fig. 9, typical of the latest period of Gothic architecture, is constructed from four centres, two in the springing and two in the reveals below. To draw, divide the span on the springing line into four equal parts ; on that portion of the springing lying between the two outer divisions construct an equilateral triangle as shown, and produce the sides to intersect the jambs or reveals. A horizontal line joining the intersections will form the base of a second equilateral triangle, and the two base angles in each case, points 1, 2, 3, 4, contain the centres for describing the arcs. The sides of the triangles produced across the face of the arch give the leading bed joint, and the point of junction of the respective arcs. The bed joints in each section are made to radiate from the centre from which that section is described.

**The Horseshoe or Moorish Arch**, Fig. 16, is generally associated with Saracenic or Arabic architecture ; elsewhere it is used as an ornamental rather than a constructional feature. Alternative treatments are shown, the principal characteristic being the carrying of the curve around below the centre line, no other type of arch sharing this peculiarity.

**The Stilted Arch**, Fig. 12a, which springs, not from the impost where all other arches commence but at some distance above, was a constructional device in Early English architecture to bring the crowns of cross vaulting into line or level. Apart from this peculiarity, there is no distinctive feature from the ordinary arch, and " stilting " may be applied to arches of any contour.

**The Basket-handle or Three-centred Arch**, Fig. 13, is obtained by dividing the span into three equal parts and constructing an equilateral triangle upon the centre part, as shown. The three angles of the triangle contain the centres, and the sides produced across the face of the arch give the leading bed joint and junction of the curves.

**The Ogee Arch**, Fig. 14, is described in detail under Carpentry Arches.

**The Squinch Arch**, Fig. 15, is so named from its position, not its shape, which may vary with circumstances. Squinch is Old English, or Saxon, for corner, and in this connection means an arch turned across a corner. It is often used to support a diagonal wall beneath an octagonal spire, where the tower changes from square to octagonal.

The other sketches, Figs. 10, 11, 12, are comparative groupings of four chief types of arches: the " flat," the " segmental," the " round " and the " pointed."

**Carpentry Arches**, page 171.—The arched frames constructed by the carpenter, or, to be exact, the joiner, usually follow the contour of the openings provided by the mason or bricklayer, consequently their description or setting out, so far as the outlines are concerned, is similar to that described for stone arches. There are, however, differences in detail, and the necessity of dealing with these gives the opportunity of presenting alternative treatment of types that will be equally useful to the mason and the carpenter.

**The Equilateral Arched Frame**, Fig. 1, is described upon an equilateral triangle, the radius of the two arcs being equal to the span; the centres, therefore, lie in the springing line at *a* and *b*. The back of the frame is described from the same centres. The haunch joints are usually placed about one-quarter the height of the arch above the springing, and radiate from the centre of the curve—*i.e.* they are made normal to the direction of pressure.

**The Lancet**, Fig. 2, is described by constructing two semicircles on the springing line extended, with a radius equal to half the span, the centres being at *a* and *b*. The extremities of these semicircles, points 1 and 2, provide the centres for striking the curves. The haunch joint is one-fourth the perpendicular height above the springing.

**The Drop Arch**, Fig. 3, is made in varying degrees of depression to suit the designer. The span and rise being given, construct a triangle upon the springing line with the required altitude. Bisect the inclined sides of the triangle and produce the bisectors to intersect the springing line in points 1 and 2. These are the required centres.

**The Tudor Arch**, Fig. 4, is constructed by dividing the span on the springing line into four equal parts, describing semicircles equal in radius to the half span, upon points 1 and 3 as centres; these describe the haunch arcs. For the centres of the crown arcs, describe quadrants from *a* and *b*, intersecting the jambs in points 2 and 4, which are the required centres. To find the joint line, join points 1–2 and produce.

**Two other Four-centred Arches** are shown in Fig. 5. On the right half the span is divided into six equal parts,

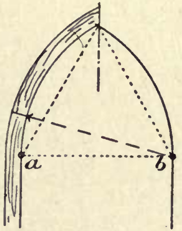


Fig. 1.

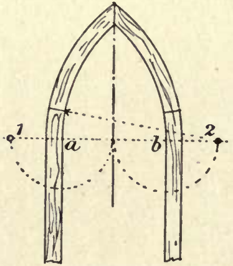


Fig. 2.

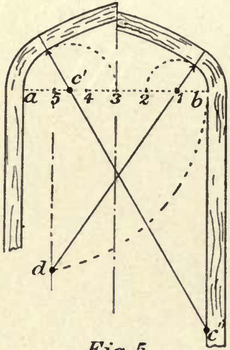

c'
a
5
4
3
2
1
b
d
c

Fig. 5.

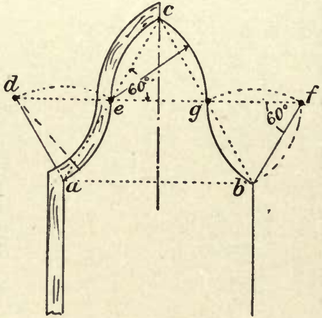

c
d
60°
e
g
f
60°
a
b

Fig. 6.

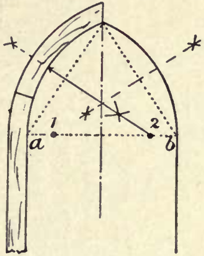


Fig. 3.

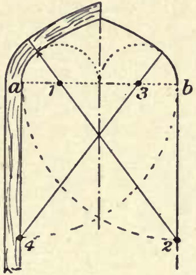


Fig. 4.

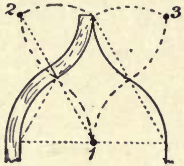


Fig 7.

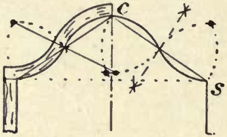


Fig. 8.

Carpentry Arches

and a perpendicular dropped from 1 and 5. These points are also the centres of the quadrants containing the lower centres, and the remainder of the construction is clearly indicated in the figure. On the left the span is divided into four equal parts, and an equilateral triangle constructed upon the middle two give the centres as shown.

**The Cyma Reversa or Wave Arch,** Fig. 6, is produced upon a triangle of 60°, the span *a–b* forming the base. Bisect the inclined sides *a–c* and *b–c* in points *e* and *g*, and draw a line through the points parallel with *a–b*. With *e* and *g* as centres and the length *e–g* as radius, describe the arcs *e–c* and *g–c*. With the same radius, describe arcs from *a* and *b*, intersecting the line of centres in *d* and *f*. These locate the two centres for the remaining arcs of the curve.

**The Ogee Arch,** Fig. 7, is a form frequently adopted for pavilion roofs, also for window frames. To describe it, construct an equilateral triangle on the span. From the three angles of the triangle with radius equal half the span, describe arcs intersecting the sides as shown at the points of intersection; describe other arcs intersecting the first, in points 1, 2, 3. These points furnish the centres for describing the curves. A line joining points 1–2 or 1–3 gives the position and direction of the joints.

**The Bell Arch or Reversed Ogee,** Fig. 8, is drawn similarly. Join the crown to the springing by the line *c–s*. Bisect this line, which gives the point of junction of the curves of contrary flexure. With a radius equal to half the length of *c–s*, describe intersecting arcs above and below the line. These intersections give the centres of the required arcs. If a joint is required it must be upon a line joining the centres of the reverse arcs.

**Compound Curves.**—There are many of these, and a few that are considered of most service to artisans in the building trades are dealt with.

**The Helix,** Figs. 1 and 2, page 173, are the plan and elevation respectively of a cylindric helix, sometimes miscalled a spiral. The spiral is a curve of continually

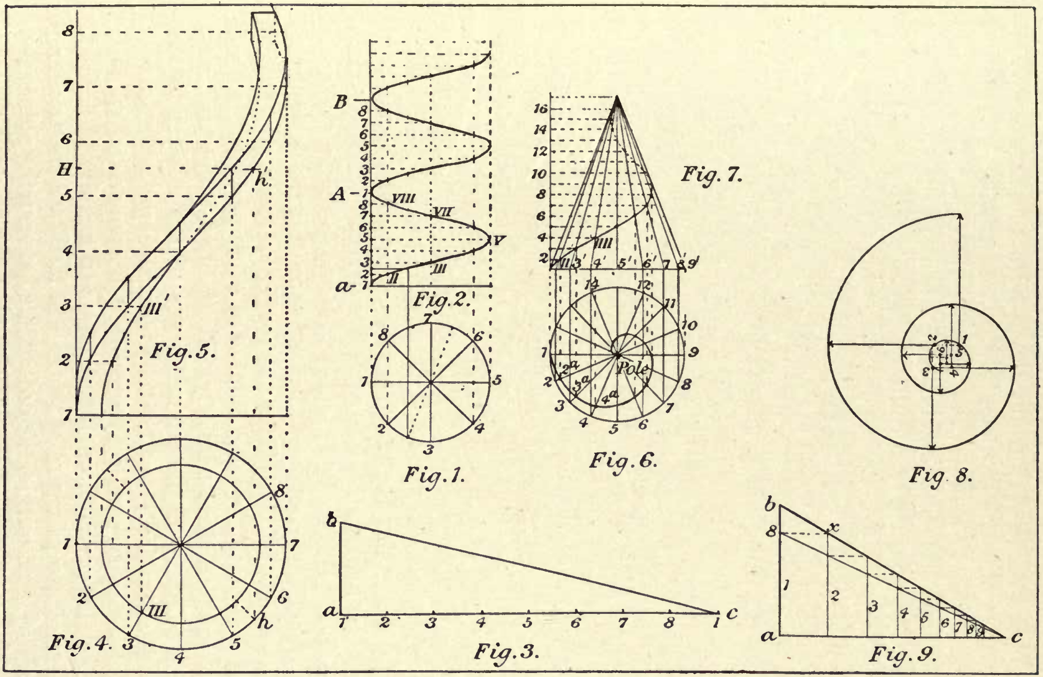


Fig. 4.
Fig. 5.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
H
h
III
III'
A
B
a
b
c
x
Pole

Compound Curves

Figs. 1 to 3. The Helix. Figs. 4 and 5. A Wreathed Handrail. Figs. 6 and 7. The Spiral. Fig. 8. The Scroll. Fig. 9. A Radius Gauge diminishing radius, no two portions being alike. The helix is a curve of constant distance from its axis of revolutions, its opposite portions being symmetrical. The plan of a helix may be a circle or an ellipse ; the elevation is similar in each case. The projection of a helix as shown in Fig. 2 does not give its true contour, because the curve itself is formed upon a cylindric surface, whilst the projection is upon a plane ; but the projections are necessary for many purposes, one of which is shown in Figs. 4 and 5. Fig. 3 is the development of the helical curve shown in Fig. 2, *b–c* being the helix, which, it will be observed, is a straight line. *a–b* represents the distance which one revolution of the helix rises or advances, and this is called the " pitch," a term which is not strictly correct ; the distance *a–b* upon either figure gives the amount of pitch or inclination of the curve, but it is not the inclination itself. In the example, one in. (by scale) is taken for each complete revolution of the line ; therefore such a helix is termed one of an inch pitch. A common example is the thread of a screw. The distance between the highest part of a thread and the highest part of the next one above it, upon the same side, gives the " pitch " of that screw, otherwise expressed, as so many threads to the inch.

**To draw the Helix.**—Describe a circle of the required diameter ; divide this into a number of equal parts, as shown in Fig. 1. Draw a line parallel with one diameter, and erect a perpendicular, as *a–B*. Set off upon this the desired rise or amount of " pitch " for one revolution, as *a–A*. Divide this space into the same number of equal parts as the plan, and number them similarly. Next draw projectors from each point upon the circumference of the circle into the elevation, and intersect them by horizontal projectors drawn from the correspondingly numbered divisions between *a–A*. Trace the curve through the points so found. If desired, intermediate points may be used to facilitate the freehand drawing, as shown by the dotted line between the points 2–3 and its projector, shown in full lines. Note that at each revolution the curve repeats upon the projection.

**To draw the Development,** Fig. 3.—Make the straight line *a–c* equal in length to the circumference of the helix in plan; draw *a–b* perpendicular and equal in length to the given rise *a–A*, Fig. 2; join *b–c*, then *b–c* is the true inclination of the helix. A wreathed handrail to a circular stair is an example of a helical curve, and in Fig. 5 a projection of one is given.

**To draw the Projection of a Wreathed Handrail.**—Let Fig. 4 be the plan of the rail and the radiating lines may be considered the risers of the steps beneath. For convenience of explanation we will consider first the outside of the rail in plan, and the under arris in elevation. Draw the perpendicular 1–8, Fig. 5, as a projection of point 1 in the plan; set off upon it eight divisions equal to the distance between the points in plan; this, of course, would not be so in practice. The "rise" of a step is always less than its "going," but the above arrangement facilitates explanations.

Draw horizontal projectors from each division and intersect them by perpendiculars from the correspondingly numbered points in the plan. Draw, either freehand or by aid of the French curve, a continuous line through the points so found. This will produce the lower external arris as shown. Now if we consider the rail to have vertical sides, as it actually does in practice, before it is moulded, it will be obvious that the top external arris will be directly over the line just drawn, and is represented in the plan by the same circle. Therefore all that is necessary to obtain the projection of the top edge is to utilise the same projectors by producing them upwards as shown in full line, and making them equal in length to the thickness of rail; a second series of points will thus be obtained through which to draw this curve. The two inner arrises are obtained similarly, but in this case, though we use the same heights as before, we project from the inside circle in plan, as, for example, on radiator 3, point *III* taken into the elevation becomes point *III′* upon the horizontal projector 3. As the rail winds around the cylinder the view of the inner edge is intercepted by the outside of the rail, therefore that portion is shown by a dotted line.

**The Spiral** is a curved line whose consecutive points continuously and uniformly approach or recede from a certain fixed point called *the pole.* A line drawn from the pole to any point in the curve is called its radius at that point. Herein lies the essential difference between a true spiral and a helix ; the radii of a helix are all of one length ; the radii of a spiral are all of different lengths. The spiral ascends upon a cone, the helix upon a cylindric or ellipsoidial prism.

**To draw a Spiral Curve.**—Draw the generating cone and its plan as Figs. 6 and 7. Divide the plan into any number of segments by radial lines through its centre. Project their extremities into the elevation, as indicated by the figures. Join the points upon the base to the apex, thus producing a series of lines upon the surface of the cone of which the first drawn radial lines are the plans. Next erect a perpendicular to the base, and upon it set off the same *number* of equal divisions as are shown in the plan. These may bear any proportion to the " going " in the plan, and, as in the helix, they indicate the pitch. Draw horizontal projectors from these divisions 2, 3, 4, etc., to the correspondingly numbered sections upon the surface of the cone, and trace the curve through the points so found ; this gives us the " rising spiral."

To find the plane or spiral " scroll," Fig. 6, drop perpendiculars from the points found on the surface of the cone upon the similarly numbered radii in the plan, as, per example, *IIII* to $4^a$, and trace the curve through these points.

**The Scroll**, Fig. 9, is a plane spiral curve, also known as the volute. There are several methods of drawing these by diminishing arcs of circles ; some more applicable to handrails are given in the author's " Modern Practical Joinery." The one described here is more suitable for architectural draughtsmen.

We have first to obtain proportional radii, see Fig. 9.

Draw *a–b* equal in height to the largest radius required or given; number this 1. At right angles, draw *a–c* at any convenient length; join *b–c*. We have next to decide how many centres to use; this is a matter of judgment and depends upon the size of the scroll. In the example, ten has been chosen. Then divide *a–b* into ten equal parts; at the eighth part draw a line parallel to *a–c*, intersecting *b–c* in *X*; draw a perpendicular to *a–c* from this point, which gives No. 2 radius. Next join point 8 to *c*, and where this line intersects radius 2, draw a similar horizontal to the first, and so obtain radius 3; proceed in like manner to the tenth. We have now a series of radii reduced in geometrical progression. To use them, take radius No. 1 in the compasses and describe a quadrant as in Fig. 8. Draw lines from the centre at right angles to each other, and upon the one at which the arc finishes set off the second radius, marked centre 2, measuring from the circumference. Describe a quadrant with this, and proceed in like manner with the remaining radii. The scroll might be continued until it finished into the "eye" or point, but to do so would hide some of the centres and make the drawing less clear.

In Fig. 8 the numbers are placed close to the centres from which the radii spring, and they read towards the radii they refer to.

## CHAPTER XI

## WORKSHOP DRAWINGS

Difference between "Working" and "Workshop" Drawings. Methods of preparing Workshop Drawings for Various Trades. JOINERS' RODS — difference between setting-out material and setting-out rods. Purposes of a Rod—what it should contain, and what it should not. Standard Widths of Rods. How to indicate Sections, Broken Sections, Dimension Lines. Method of dealing with Long Rods. Where to start Setting-out. Datum Points. Setting-out a Venetian Window—details of procedure. A Pair of Circular-headed Doors and Finishings—the necessary Rods. What the "Height Rod" should contain. The Elevation Rod—method of setting it out. The Question of Joints. BRICKLAYERS' SETTING-OUT. A Semicircular Arch in a Circular Wall, with Parallel Jambs and Level Soffit—drawback of the "centre" method. The Geometrical Method, obtaining Templets and Soffit Mould. A Circle-on-Circle Opening with splayed Jambs and Soffit. Producing the Section. Obtaining Soffit Mould. Setting out an Octagonal Chimney Stack. Alternative Methods of Setting out Octagons. Obtaining the Bevels for cutting Templets

THE term "workshop drawing" is used to differentiate those drawings prepared directly for the workman's use in setting out his material; from the detail drawings prepared by an architect for the use of the builder, which are generally known as working drawings. (For a fuller definition of these, see Chapter I.) In a sense, both of these kinds of drawings can be said to be working drawings, as they have to be "worked" to, but in the case of small scale drawings a certain amount of translation or calculation is necessary before the work can be put in hand, whilst the drawings now to be described are invariably made full size, so that the workman can apply his material directly to them for the purpose of setting it out, and shaping it. These drawings, in the case of carpentry work of large size, are usually set out with chalk upon a large floor or platform ; in the case of joinery work, in pencil, upon planed and whitened boards termed " rods," or occasionally upon large sheets or strips of white paper, the kind used by paperhangers for lining ceilings. Masons' and carvers' work is usually set out on sheets of brown paper, a special stiff and smooth-surfaced kind ; bricklayers' work either on " centres " or upon large battened " boards," or on slabs of slate.

**Joiners' Rods.**—The preparation of these is usually described as " setting-out," but the term should not be confused with the operation of placing shoulder lines, and marking bevels, scribes, mortises, tenons, dovetails and various other joints upon the prepared material, which is also collectively known as " setting-out " in the workshop. With this latter operation, which has practically nothing to do with drawing in the ordinary sense of the term, this book does not deal, but so far as it refers to joiners' work the subject has been fully described in the author's " Modern Practical Joinery."

A joiner's " rod " is a full-size section or sections of the piece of work to be executed, and is intended to facilitate the actual setting-out of the various members of the construction and to obtain the correct quantities of the material, also to be a convenient record for future reference in connection with the same, or other work upon the building. Obviously, to meet these requirements the drawing should be exact as to shape and dimensions, should be clear and definite as to the intentions of the person setting it out, and, saving actual blundering or ignorance upon the part of the workman, it should be impossible for it to have more than one reading.

Foremen and " setters-out " will, of course, have different opinions as to what is necessary to place upon a rod, or what to omit, and the instructions given herein, though based upon the author's lengthy experience in such work, can only be taken as guides, whose course it may be necessary to vary with circumstances. In the author's opinion the simpler a rod can be made the better it will be for the workman—*i.e.* no superfluous lines should be employed, although such lines represent an edge or a member in the finished work, and are upon the architect's drawing; if they are not actually required for the subsequent setting-out purposes they are out of place upon the rod, and likely to lead to errors. Inexperienced setters-out sometimes pride themselves upon their rods being "pictures," and complacently state that every line in the job is there. Probably true, to the discomfiture of the workman and loss to the employer.

Compare the two sides of Fig. 3, page 186, and consider which is the easier to understand. All that is absolutely necessary to obtain the moulds required for the job is shown upon the right-hand half, and the left-hand half, though a more correct *drawing* in elevation, does not contain all that is necessary, and it contains much that is useless and liable to mislead.

It often requires serious consideration as to the best way to set out a piece of work on the rod; the setter-out must form in his mind's eye the completed job as the designer describes it in the drawings and specifications, and must decide upon the main principles of construction; also, if it is a large piece of work, whether it can be fixed, or can be conveyed from the workshop to the building, in one piece. He, of course, has not to consider the minor details of construction, the "putting together"; this is a matter for the workman, but careful planning is often necessary to ensure the proper fitting and arrangement of adjacent parts, in elaborate finishings, etc., that have to be set out in sections or portions upon several rods. Having broadly decided upon the construction, the next essential is to see that every piece or member of the structure has its length, width and thickness shown, and that parts that are in sections are clearly distinguished from those shown in elevation, upon the same drawing. This latter is usually done in a manner similar to ordinary drawings, by pencilling the annual rings in wood, in a conventional manner, and indicating brick or stone work by straight lines ruled at an angle of 45° on the parts that are given in section. Some setters-out prefer to use coloured pencils to indicate these materials: red for brickwork, blue for stone, yellow for iron, etc. In any case the sectioning should be merely indicative, and not elaborate. The examples in this book, having necessarily to be considerably reduced, appear to err in this direction, consequent upon the closing in of the lines in the reducing process. The method shown in Figs. 5 and 6, page 183, of short straight lines around the outlines of the section, is a very good and clear method, and allows of writing upon the member, which is sometimes advisable.

No graining should appear upon elevations, as a stray line may be mistaken for a working edge. If some special kind of wood is required in a certain place, such as a mahogany strip on the edge of a deal shelf, it is better either to write the description or to colour the portion red, or such other colour as will best indicate the material to be used. All chief measurements, such as clear size of openings, should be figured in with arrow-head dimension lines, and, when a broken section is given, the true dimensions should always be figured across, as shown in Fig. 1, page 186. A broken width section has frequently to be given, as in the example of the width rod just quoted.

Rods are seldom used wider than 11 in., and more usually 9 in., except in cases where the work cannot possibly be draw upon such widths. Wide boards are very inconvenient to handle, occupy a great deal of bench space, and thus make the setting-out costly. It is generally quite possible to show all three dimensions of a job upon a narrow rod, as in the examples (Figs. 1 and 3, page 183, and Figs. 1, 2, 4, page 186). Fig. 1 gives the width of a door and the finishings, but not the width of the linings or thickness of the wall in which the doorway is made. This is shown in a separate drawing made upon the other side of the rod (see Fig. 2); all the vertical dimensions are shown on the "height rod," Fig. 4. Thus with these three drawings the joiner can obtain all the dimensions of every straight piece in the job. The curved portion requiring special treatment will be referred to presently. No broken lines must be made in the *length* of a section. Obviously, if this is done, the rod is useless for its chief purpose, the actual laying down of the stuff upon it, and the transference thereto of the shoulder lines, etc.

The breaks in the examples at *A*, Fig. 4, and *B–B*, (Figs. 2 and 3, page 183), are introduced to avoid making the drawing to such minute scale that the details would be indistinguishable, but, of course, in actual setting-out, this would not need consideration. When a job is so large that more than one rod is required to accommodate its length, as, for example, a dado framing for a 30-ft. corridor, the adjacent ends should be squared, and correspondingly numbered or lettered within circles, and the exact distance between two near points in the framing should be figured in, as a check, in case the rod should get accidentally cut short. The wall or other "fixed point" should always be shown on the width rod, and the floor line upon the height rod, and these datum points are the ones to commence with.

In setting out linings to openings, or frames to fit into them, lay down the dimensions of the opening first, as ascertained upon the building or from other data, and build the framing, as it were, around or in them; by this method the danger of making a fitting either too large or too small for the opening will be avoided.

Work from the face, or best side of the job—*i.e.* from the inside of a window or the more important side of a door. Where two opposite sides of a job are alike, as the two boxings of a sash frame, do not set out each independently, but set out one side completely, then carefully gauge each line from the face edge and run it to the opposite side and complete the section therefrom, which ensures accurate duplication.

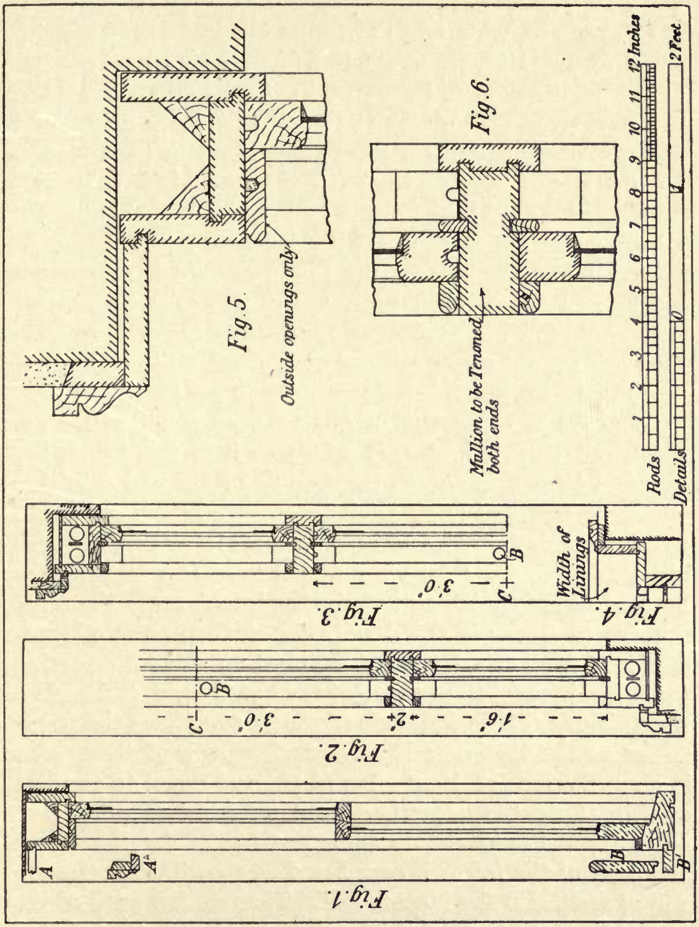


Fig. 5.
Outside openings only
Fig. 6.
Mullion to be Tenoned both ends
12 Inches
2 Feet
1 2 3 4 5 6 7 8 9 10 11 12
0
Rods
Details
Fig. 3.
3' 0"
C
B
Width of Linings
Fig. 4.
Fig. 2.
C
B
3' 0"
2"
1' 6"
Fig. 1.
A
A^A
B
B'

Joiners' Rods—A Solid Mullion Venetian Frame

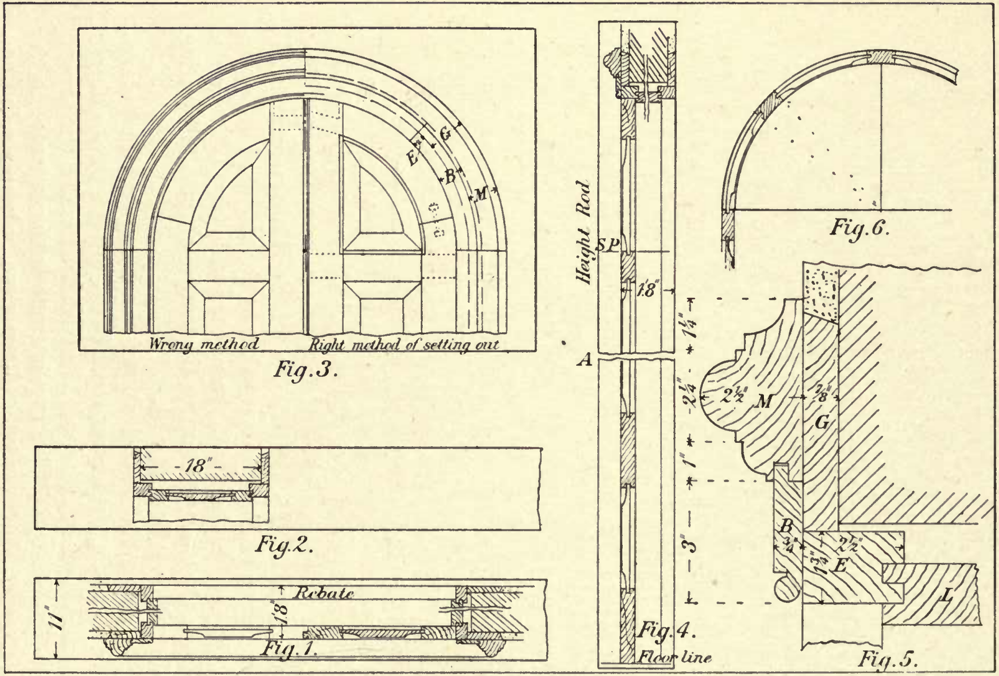
**A Solid Mullion Venetian Frame.**—This is an example of how the work may be set out, when the job is wider than the rod to be used. Fig. 1 is the height rod, and it contains a section taken through one of the side lights, which are fixed, the central pair of sashes only opening. This is indicated by the grooves for the cord at the head. The rod is 9 in. wide and the frame is fixed within a 4½ in. reveal in a 13½ in. wall, which, as will be seen by the enlarged detail, Fig. 5, leaves 9¾ in. to be covered by the frame and the lining. As the architrave projects beyond this, it is obviously impossible to put it all in on 9 inches. One method of showing the parts that would come beyond the edge of the rod is given at *A* and *B*, Fig. 1. At the head, a broken section is shown with required width of lining figured in ; at the bottom the window board is drawn full width, and its position indicated at *B′*. An alternative method of showing the soffit and architrave is given in Fig. 4. Here it is set out across the rod at one end, all that is necessary for the workman being the width of the jamb lining.

To avoid showing the details to very small scale, the width rod, Figs. 2 and 3, is drawn as if in two parts, the assumed joint being at *C*, the middle of the central light. Of course, this is merely a book device ; the actual rod would be in one length. The usual procedure in setting out this rod would be, after squaring across lines to represent the bottom side of the sill and of the head, to draw in the brick opening as shown in the detail, Fig. 5, then point off, successively, from this, the outside lining, outside sash, parting bead, inside sash, the overlap of the guard bead, and finally, the thickness of inside lining, which completes the frame so far as the thickness is concerned. Each of these lines is gauged from the front edge of the rod down to the line of sill. Then the latter is drawn in by aid of a templet, or to the required section according to the details. Next the head of the frame is completed as shown, then the top rail of sash, also the bottom rail. Then, in the path of the top sash, mark the sight line of the bottom rail and tick off below, the thickness that the meeting rails are intended to be, in this case 1⅝ in. ; then, if half of the distance between the lower point and sight line of top rail is set off from the aforesaid two points successively, it will place the meeting rails at their proper thickness exactly midway between the sight lines of the top and bottom rails. The drawing-in of the guard beads will complete the height rod.

Make a note on the rod that the wide bead shown at the head is to be placed in the outer openings only.

**A Pair of Circular-headed Doors and Finishings** are shown on page 186. The width rod, Fig. 1, gives the necessary lines for setting-out the rails of the doors, width and dishing of the panels, housing or grooving in the soffit of the linings, width of the edging *E* (see enlarged details, Fig. 5), also width of the head of the grounds, and sight lines for moulds and sections of the architrave. The rebate on the off side of the linings is perhaps not strictly necessary, but it gives the joiner a better idea of the job and is usually put in. The width across the linings is shown, as in Fig. 2, either upon the back of the rod or farther down its length upon the same side as may be found convenient. The height rod, Fig. 4, gives the heights of the various members between floor and springing, the parts above the springing (marked *SP*) are given merely for completeness, or to make the job clear to the workman, as he does not, or should not, take any dimensions from it; all of these must be taken from the elevation rod, Fig. 3, and the necessary data for setting-out the height rod are taken from Fig. 5. For instance, although the section of the linings and architrave shown on Fig. 4 is one taken at the centre of the opening, that of the door is taken at the inside edge of the stile, which is the nearest point to the centre where a full section of the rails can be obtained.

**Elevation Rod.**—All shaped work requires an "elevation rod"—*i.e.* the curves must be set-out full size to obtain the moulds for marking out the stuff from which the several members are cut. This requirement is the keynote to the setting-out. Some remarks have already been made upon the uselessness of embellishing the rod with lines that are not necessary—*i.e.* not required for the actual setting-out of


Wrong method
Right method of setting out
Fig. 3.
E
G
B
M
Height Rod
SP
1.8"
A
1¼"
2¼"
1"
3"
Fig. 4.
Floor line
Fig. 6.
2½"
M
⅞"
G
B
¾"
2½"
E
1⅞"
L
Fig. 5.
18"
Fig. 2.
11"
Rebate
1.8"
Fig. 1.

Setting-out Joiners' Rods—Example—a pair of Circular-headed Doors and Linings

Fig. 1. Width Rod. Fig. 2. Rod for Linings. Fig. 3. Elevation Rod. Fig. 4. Height Rod. Fig. 5. Enlarged Details of Architrave. Fig. 6. Soffit Rod

the work. To make this quite clear: the architrave moulding shown in section at top of Fig. 4, and in detail at Fig. 5, contains, in its finished state, eleven arrises, which require eleven lines on the rod to indicate them. Now all that is required to draw the moulds are four lines, the inner and outer edges of each piece. When the stuff is cut to this shape, the machinist will automatically produce all the others with correctness, by working the face edge against the "spindle," therefore these extra lines are not only useless on the rod, they are confusing, also when the workman is trying the moulds on, he requires to keep following the path of such lines around, to make sure he is dealing with the right one.

**To set the Rod out.**—Draw the springing line and a centre line at right angles to it, squaring from lower edge of board. Draw in the frieze rails and stiles, also section of the architrave on one side exactly as they occur on the width rod. Strike the door head with a beam compass, also the curved panels; mark in the radial joint line. Next consider what is required in the way of moulds. There will be, in the present case, one each for back architrave *M*; bed mould *B*; ground *G*; solid rebate *E*; soffit stile or head *L*; and panel of same, also one for panel of door; this latter is shown in the second line on right side of door. The various moulds are indicated by the above letters in the example, and the same letters are used on the enlarged section for reference. To avoid confusion, the soffit is shown separately in Fig. 6, but as the lines would not be so close together when set out full size, this could be superposed on the same rod.

It is considered somewhat *infra dig.* by most joiners to have the various constructive joints shown on the rod, as they are presumed to know the rudiments of their trade, but as the correct size and disposition of tenons, etc., is of more importance in circular work than in square, it is very usual to set these out on the rod. The tenon on the left of Fig. 3 is the way *not* to do it; that on the right the correct way.

In the first case, probably half the tenon would break off in the wedging up, through being cut across the grain. The joints in the door head would be grooved and cross-tongued and handrail-bolted; those of the architrave, dovetail-keyed; the grounds, half-lapped and screwed; and those between soffit and jambs, dowelled.

**Bricklayers' Setting-out.**—Circle-on-circle work, Figs. 1 and 2, page 189, show the half elevation and half plan of a semicircular arch in a circular wall, the jambs, reveals and soffits of the opening being perpendicular to the chord line of the arc, or, as it is more usually described in the trade, an opening with parallel jambs and soffit level at the crown.

These arches are invariably made in gauged or cut work, and the usual practice is for the carpenter to make a true "centre" to fit the required opening exactly in both plan and elevation, and the bricklayer, having first made an elevation on his bench board full size, applies the centre to the drawing and marks the intrados spacing of the arch on each face in turn, and then joins up the points across the soffit with a straight edge, thus obtaining the shape of each brick on the soffit. This method has its drawbacks, as each brick must be scribed to the faces of the "centre," and it is necessary for the carpenter to make a "centre" with compound curves, which is much more expensive than an ordinary barrel centre with which the job could be done equally well by the method of setting-out now to be described.

**To set out the Elevation.**—Draw the springing line parallel to the edge of setting-out board, and far enough upwards to get the plan underneath as shown in the example. It is usual to strike the entire arch, but one-half is really sufficient. Draw a centre line with the square, and at the intersection as centre and the "trammel rod" set to the required radius, strike the intrados and extrados of the arch, set out the springers and the key brick, the first on the springing line and the second equally on each side

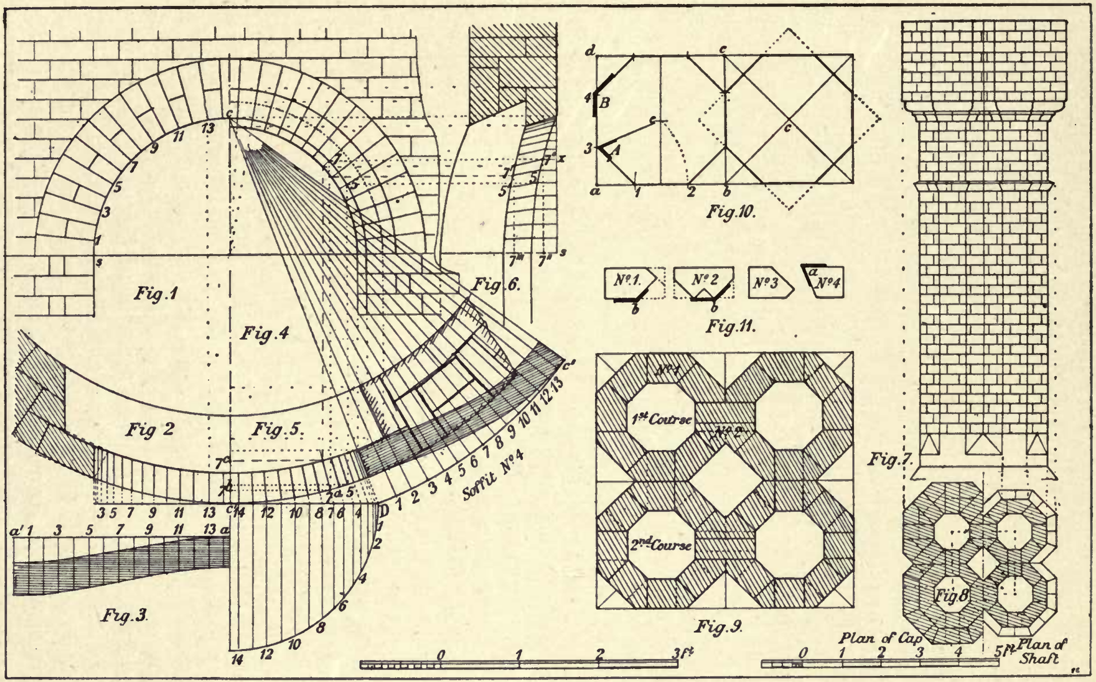


Fig. 1
Fig 2
Fig. 3.
Fig. 4
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8
Fig. 9.
Fig. 10.
Fig. 11.
Soffit No. 4
No. 1.
No. 2
No. 3
No. 4
1st Course
2nd Course
Plan of Cap
Plan of Shaft
0 1 2 3ft
0 1 2 3 4 5ft

Setting-out for Bricklayers—Examples in Circle-on-Circle Work—Octagonal Chimney of centre line, then space out the extrados equally, with the compasses set to the thickness of a brick, and, if the arc will not divide equally with this, reduce the space until an equal division can be obtained, then draw the joints radiating from the centre to the division points. This will give size of templet for the faces, to which the cutting box should be made.

Next, strike out the plan on the same centre line, and square the reveals and jambs from edge of board. Draw in the plans of the bed joints by moving the square around the soffit successively, as shown by the numbers on Fig. 1 and indicated by dotted projector at joint No. 13. This gives the soffit joints or end shape of the bricks in plan only, but not their real size; to obtain this a stretch-out of the soffit as shown in Fig. 3 is required. To obtain this, make the line *a′–a* equal in length to the curve line *S–C*, Fig. 1, and this can be done accurately enough by setting the compasses to the thickness of a brick on the soffit as seen in the elevation, and stepping it along the line the number of times there are bricks in the arch. (Only one-half is shown, and this is usually sufficient.) Next draw perpendiculars from the division points of indefinite length, with the square. Then draw a line tangent to the plan curve—*i.e.* parallel with the springing line—and carry the joints across to it, as shown by dotted projectors. Number each set as shown, then, measuring across each joint with the compasses from the tangent line, transfer the lengths to the stretch-out line upon the corresponding number thereon, and so obtain a series of points through which the curves can be drawn, by bending a lath to fit them. Now we have the soffit as it would appear if stretched out flat, but as the arch is curved, this does not really give the accurate angles of each individual brick, and we must bend this stretch-out over the centre before we can get the true shapes. The best way to do this is to trace off the stretch-out on a strip of tracing linen, then to fasten this upon the "centre" with tacks keeping the crown at its proper projection beyond the springings as shown in Fig. 2, the bevels can then be taken and the cutting proceeded with.

**A Circle-on-Circle Opening** with splayed jambs and soffit is shown in Figs. 4, 5 and 6. Obtaining the shape of the bricks for this arch is a somewhat more complicated process than the last case, which was, in effect, the determination of the penetrating section of two right cylinders, whilst this one is the penetration of a right cylinder by a semi-cone, and the method of obtaining the shape of the soffit is based on the process of obtaining the covering of a cone as described on page 159. Much of the previous instruction will apply to this case and it will only be necessary to recapitulate.

Having struck the arch, draw the bed joints to the centre, and project the soffit ends into the face of the plan, as shown by the dotted projectors 5 and *7a*. Produce the side of the reveal to the centre of the plan curve *C*, and draw the plans of the joints all to the same centre. These lines have not been produced in the example, to avoid confusion.

**To draw the Section,** Fig. 6, project the crown and springing of the arch across, as shown, to the face of the wall; continue the face line down to the springing to provide a plane to measure from. Project horizontal lines from the intersections of each joint with the back and front edges of the arch. One or two only of these are shown, and one will be traced throughout as a guide to the rest. Take the top bed joint of the seventh brick (point 7 in Fig. 4), project a horizontal across to *X*, also drop a projector from same point into the plan at *7a*; carry this to the centre line in point *7b* by a perpendicular therefrom. Transfer the distance of *7b* from C′ to the line *S*, Fig. 6, which gives point 7″; erect a perpendicular to meet the horizontal projector *7–x* in point 7°, which is a point in the curve to be drawn. Follow out each joint in like manner on each edge of the arch, and draw the curve through the points so found.

**To obtain Soffit Mould.**—This has been laid out over the plan, and the mould is hatched to make it distinctive.

Draw the tangent line *C–D*, and produce the splayed reveal to meet it. With *C′* as centre and *C′–D* as radius, describe an arc; this is the base of the semi-cone *C–C′–D* laid down. With the apex *C* as centre and side *C–D* as radius, describe the arc *D–C″*. Next, produce the joint lines in the plan to meet the line *C′–D*, and thence erect perpendiculars to cut the curve in points 1 to 14. Transfer these divisions to the curve line *D–C″*, numbering them to correspond. Draw lines from these points to *C*, which will be the direction of the joint lines upon the soffit or "centre" developed. To obtain the faces of the arch, mark off a distance on each of these lines from *D–C″* equal to the distance of the plan of the arch from the tangent line *C′–D*, at the corresponding joint, and thus obtain points through which the curves can be drawn. Trace these on linen and fix to the conical "centre," when the true shape of each brick will be visible. The back arch is usually "axed" to shape on the centre, as it is either covered by plaster or wood linings.

**To set out an Octagonal Chimney Stack** (see page 189).—Figs. 7 and 8 are the elevation and half plans at cap and neck respectively of a group of four octagonal chimneys rising from a square base. The detail, Fig. 9, shows the method of setting-out the stack full size to obtain shapes of the bricks and the bonding. The back pair shows the course above or below the front pair, if moved forward horizontally, and the dotted lines indicate the joints below. Only two templets are required for the shafts as shown in Fig. 11, Nos. 1 and 2, and two for the cap, Nos. 3 and 4.

**Two Methods of setting-out Octagons** are shown in Fig. 10: that on the left is more suitable for draughtsmen's work with instruments, that on the right for workshop use, as this can be set out with a square and straight edge.

**First Method.**—Let the width of the required octagon be given as *a–b*. Draw a square to the given dimension as *a–b–c–d*, bisect one side and draw a centre line, bisect this line and find the centre *e*. With *a–e* as radius and *a, b, c, d* as centres, describe arcs cutting the sides of the square at 1, 2, 3, 4, etc. Join up these points and the octagon will be described.

**Second Method.**—Let the width be known. Construct a square to the given width and draw two diagonals. Mark off from centre *C*, along each diagonal half, the width of the required octagon. Through these points draw lines parallel to the diagonals, so constructing a second square overlapping the first, which will produce an octagon as shown.

The bevels shown on the left octagon are those used for marking the templets, and are placed there for convenience; they can easily be identified by the letters. *A* is the bevel for the cap joint No. 4, *B* the bevel for the shaft joints Nos. 1 and 2 (see Fig. 9 for further identification).

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